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BEHAVE: Fire Behavior Prediction and Fuel Modeling System — BURN Subsystem, Part 2

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INTRODUCTION

The BEHAVE fire behavior prediction and fuel modeling system is a set of interactive computer programs. BEHAVE provides mathematical prediction models in one easy-to-use package. This paper describes prediction capabilities that have been added to the system.

Since 1984, BEHAVE has been used by land managers for a variety of fire management needs. A user can tailor predictions to specific needs based on the resolution of the input and interpretation of the output. For example, windspeed might be measured on site for real-time prediction of wildfire behavior. On the other hand, windspeed can be assigned a range of values in order to make assessments for planning purposes. Example uses of BEHAVE predictions are determining appropriate suppression action, predicting the growth of a wilderness fire, prescribed fire planning, setting dispatch levels, and after-the-fact predictions for an investigation.

This paper is the third in a series of papers that describe the BEHAVE system. Burgan and Rothermel (1984) described the FUEL subsystem of BEHAVE, used for designing custom fuel models. Andrews (1986) described the initial BURN subsystem, the operational fire behavior prediction part of BEHAVE. This paper covers additions that have been made to the BURN subsystem.

Part 1 of the BURN manual described the FIRE1 program. This paper is Part 2 of the BURN manual and describes additions to the FIRE1 program and the new FIRE2 program. The information in Part 1 is still valid. Worksheets for all modules in the FIRE1 and FIRE2 programs are in this manual (appendix B).

We assume that you are familiar with BEHAVE, specifically with the material in Part 1 of the BURN manual. References will be made to that paper (Andrews 1986) by page number (for example, Part 1, p. 23). As with Part 1, the emphasis of this paper is on description of the prediction models. You are responsible for supplying valid input and for properly interpreting output.

OVERVIEW OF THE BEHAVE SYSTEM

A diagram of the BEHAVE system design is shown in figure 1. The BURN subsystem previously consisted of only one program. It now has two, FIRE1 and FIRE2. The only reason for the split is to limit program size.

BEHAVE's "user-friendly" design makes it unnecessary to provide detailed instructions on how to run the programs. Annotated runs of the FIRE1 and FIRE2 programs are given in appendix A. Operation of all of the BEHAVE programs is based on keywords. A list of all keywords in the BURN subsystem and a brief description of each is shown in figure 2. Module keywords (DIRECT, SITE, SIZE, ...) are used to specify the prediction that is desired. Operation keywords (INPUT, LIST, CHANGE, RUN) are used to enter input and obtain output. Mode keywords (WORDY, TERSE, PAUSE, ...) are used to set a switch that remains in effect until you change it. Rescue keywords (KEY, HELP) should rescue you if you get mixed up.

All of the modules can be used independently. Some of them can also be linked to others as shown in figure 3. In that case, input and/or output is carried over from one module to the next.

Input/output sheets for all modules of the BURN subsystem are included in appendix B. In some cases, they are different from those given in Part 1. To avoid confusion, the date is at the bottom of each worksheet.

The Input/Output sheets give line numbers, item names, both English and metric units, comments, and one blank. These are information sheets and not worksheets. Most users will use computer printout to document runs rather than completing a worksheet. Custom worksheets can be designed as needed.

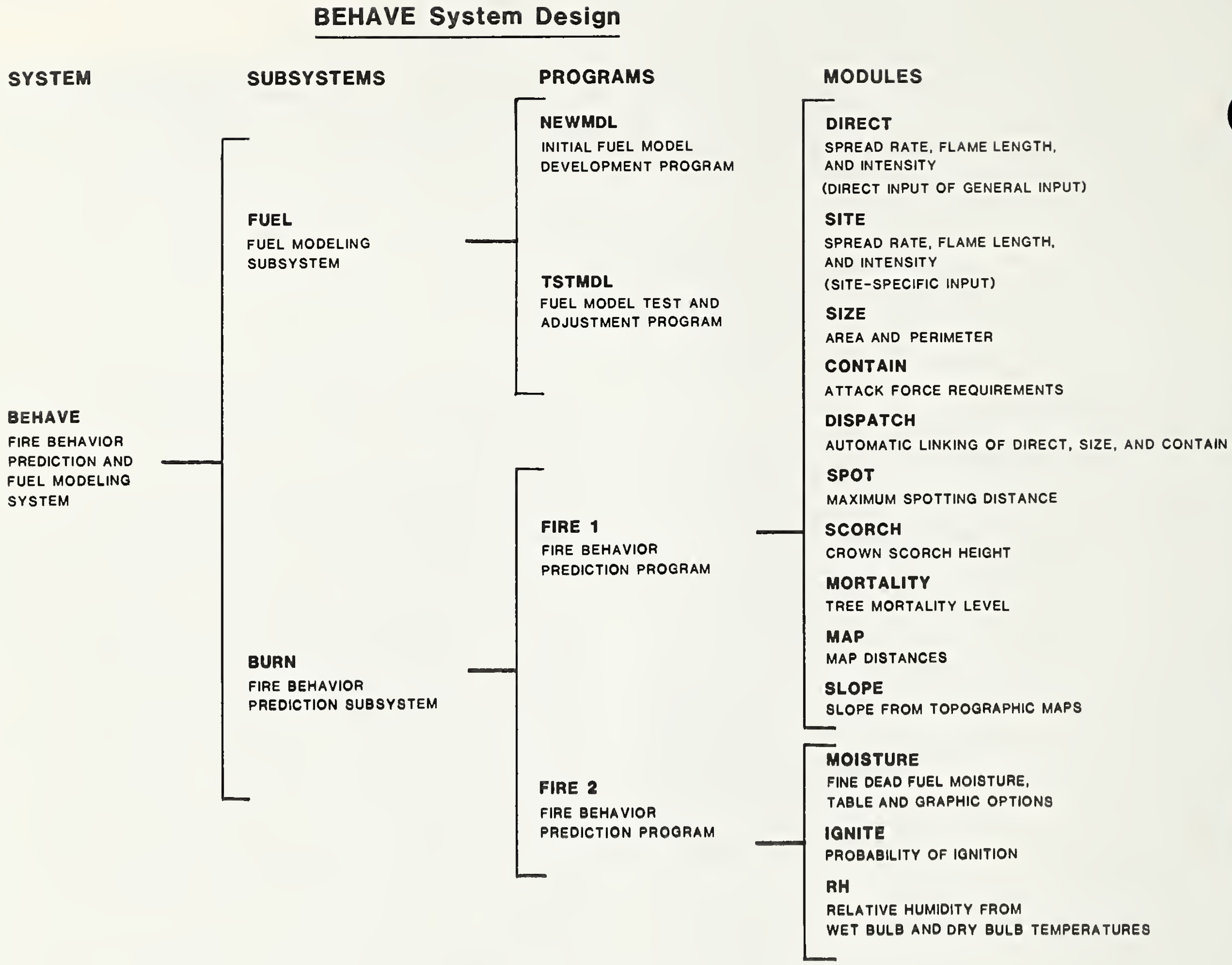


Figure 1—Subsystems, programs, and modules of the BEHAVE system.

FIRE1 only	
Module Keywords	
DIRECT	Accepts direct input of the basic values to calculate spread rate, flame length, and intensity.
SITE	Accepts site-specific input to calculate spread rate, flame length, and intensity. Fine dead fuel moisture is an intermediate value.
SIZE	Calculates area and perimeter of a point source fire.
CONTAIN	Calculates either line construction capabilities needed or final fire size.
DISPATCH	Automatically links DIRECT, SIZE, and CONTAIN
SPOT	Calculates maximum spotting distance from torching trees, a burning pile, or wind-driven surface fire.
SCORCH	Calculates crown scorch height
MORTALITY	Calculates level of tree mortality
MAP	Translates calculated distances to map distances
SLOPE	Calculates slope from topographic map measurements
CUSTOM	Specifies a custom fuel model file to be used or lists what is in a fuel model file
FIRE2 only	
Module Keywords	
MOISTURE	Calculates fine dead fuel moisture
IGNITE	Calculates probability of ignition
RH	Calculates relative humidity from wet bulb and dry bulb temperatures
FIRE1 and FIRE2	
Operation Keywords	
INPUT	Asks for all input of the current module
LIST	Lists current input values
CHANGE	Changes individual input values by line number
RUN	Does calculations and presents results
Mode Keywords	
WORDY	Gives extra messages and explanations throughout the run (default)
TERSE	Skips extra messages and explanations
PAUSE	Limits display to at most 24 lines at a time for a video display terminal (default)
NOPAUSE	No pause in display for a terminal with hard-copy output
LOG	Writes results of LIST, RUN and COMMENT to a file to be printed at a later time
NOLOG	turns off the LOG option (default)
ENGLISH	English units (default)
METRIC	Metric units
PERCENT	Slope in percent (default)
DEGREES	Slope in degrees
Rescue Keywords	
KEY	Prints the keywords that are allowed at the current point along with a brief description of each
HELP	Tells you where you are in the program and what you can do next
Other Keywords	
QUIT	Gets back to the previous level in the keyword hierarchy or terminates the run
COMMENT	Allows the user to annotate a run in a log file
STATUS	Gives the status of the mode keywords and the names of the fuel model file and the log file

Figure 2—Keyword summary for the BURN subsystem (FIRE1 and FIRE2 programs).

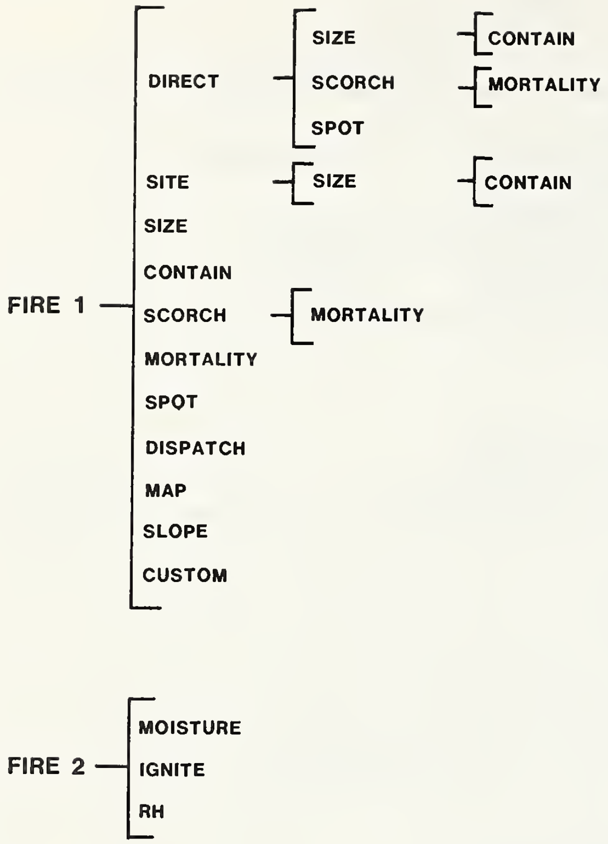


Figure 3—Keyword hierarchy for the BURN subsystem (FIRE1 and FIRE2 programs).

SUMMARY OF ADDITIONS AND CHANGES

The following is a summary of the capabilities that have been added to BEHAVE. They are listed according to keyword. The remainder of this paper describes these items in detail.

LOG/NOLOG - When the LOG mode is set, the results of LIST, RUN, COMMENT, and CUSTOM are written to a file. When the NOLOG mode is set, nothing is written to the file.

COMMENT - The user is allowed to enter a description of the run.

ENGLISH/METRIC - The option of either English or metric units can be set.

PERCENT/DEGREES - The option of specifying slope as either percentage or degrees can be set.

STATUS - The status is given for the mode keywords and, if they are in use, the names of the fuel model file and the log file.

SCORCH - Crown scorch height can be calculated.

MORTALITY - Level of tree mortality can be calculated.

SPOT - The wind-driven surface fire option has been added. Several southern tree species have been added to the torching tree option.

MAP - Calculated distances can be translated to map measurements.

SLOPE - Slope can be calculated from topographic map measurements.

IGNITE - Probability of ignition can be calculated.

MOISTURE - Table and graphic options are available for the fine dead (1-hour) fuel moisture model that is also in SITE.

RH - Relative humidity can be calculated from wet bulb and dry bulb temperatures.

UTILITY KEYWORDS (LOG, NOLOG, COMMENT, ENGLISH, METRIC, PERCENT, DEGREES, STATUS)

Several new utility keywords are available in the FIRE1 and FIRE2 programs: LOG, NOLOG, COMMENT, ENGLISH, METRIC, PERCENT, DEGREES, and STATUS. Use of these keywords is illustrated in appendix A.

Saving Results in a File for Printing (LOG and NOLOG)

BEHAVE involves a lot of interaction between you and the computer. Although it is most convenient to access BEHAVE through a video display terminal, there is often a need to save results on paper. The input and output are needed, but not all of the questions and answers.

LOG and NOLOG are mode keywords. When the LOG mode is set, the results of LIST, RUN, COMMENT, and CUSTOM are saved in a file that can later be printed. You can turn the option on and off at any time by typing LOG or NOLOG. You should get in the habit of always typing LIST before RUN. Predictions are meaningful only if they are associated with their input values.

When you first type the keyword LOG, you are asked to specify a file name. When you are finished running the program, you will be reminded that you have logged some information to a file and that you should print that file immediately and then delete it. It is important that you follow this advice to avoid wasting disk space on unneeded files.

Programs are written in standard Fortran so that they can easily be transported to a variety of computers. File handling, however, is not standard among computers. Naming of files, as well as procedures for printing and deleting them, depends on the computer being used, not on the BEHAVE system.

Adding User Comments to Output (COMMENT)

The keyword COMMENT allows you to document your logged runs. After you enter the keyword COMMENT, you may type in as many lines of description as you wish. Up to 80 characters may be typed per line; each line must be followed by a return. Two asterisks typed on a line by themselves, followed by a return, indicate that you are finished with your comment.

Changing Units (ENGLISH, METRIC, PERCENT, and DEGREES)

The previous version of BEHAVE used only English units of measurement. You now have a choice of either English or metric. The units mode can be changed at any time by typing the keywords ENGLISH or METRIC. The default is ENGLISH. It is possible, for example, to enter input in English units, enter the keyword METRIC, and then obtain the output in metric units. An example of this is given in appendix A.

Both English and metric units are given on the input/output sheets in appendix B. We have used the metric units that are acceptable to many fire specialists. Those who wish to permanently change the units used in their program may contact the authors. We will tell you where to change the source code.

You can specify slope steepness in either percentage or degrees whether you are using English or metric units. The mode can be changed at any time, using the keywords PERCENT or DEGREES. The default is PERCENT.

Checking the Status of Files and of Mode Keywords (STATUS)

The keyword STATUS allows you to check the status of the mode keywords and to see the names of the fuel model file and the log file that you are using. An example is shown in figure 4. Other examples are given in appendix A.

```
**** FIRE1 STATUS REQUEST ****

    PROMPT MODE    : WORDY
    DISPLAY MODE   : PAUSE
    LOG FILE NAME  : LOGFILE
    LOG FUNCTION   : ON
    FUEL FILE NAME: UNDECLARED
    DISPLAY UNITS  : ENGLISH
    SLOPE UNITS    : PERCENT
```

Figure 4—Use of the keyword STATUS gives the current status of each of the mode keywords.

CROWN SCORCH HEIGHT (SCORCH)

The SCORCH module of the FIRE1 program predicts lethal crown scorch height from flame length, ambient temperature, and midflame windspeed. As can be seen in figure 3, SCORCH can be used as either an independent module or it can be linked to DIRECT. Predictions from SCORCH can also be carried over to the MORTALITY module, as described in the next section.

The model developed by Van Wagner (1973) estimates the maximum height in the convection column at which the lethal temperature for live crown foliage is reached. This temperature is assumed to be 140 °F (60 °C). The scorch height model is based on the relationship of fireline intensity to temperature above the fire and on the shape of the convection column as it is affected by light winds. Flame length is used as a measure of the intensity of the heat source. The model is based on 13 test fires: eight in a stand of red pine and white pine, two in jack pine, one in red oak, and two in a red pine plantation.

Figure 5 shows the results of using SCORCH as an independent module. In this case a range of flame lengths and midflame windspeeds are examined. Notice that for a fixed flame length of 4 feet, as windspeed increases, scorch height decreases. This is caused by the flattening effect of wind as illustrated in figure 6. Although two fires may each have flame lengths of 4 feet, scorch heights will differ if the windspeeds are different.

Figure 7 shows the results of SCORCH being linked to DIRECT. On a single fire, when the windspeed increases, the flame length also increases. This effect can be seen in figure 7A where flame length is calculated for a range of windspeeds. If flame length remains constant with increasing windspeed (as in figure 5), then it must have been balanced by a change in another variable, such as increasing fuel moisture. Notice that, for this example, three combinations of 1-hour fuel moisture and windspeed result in 4-foot flame lengths. The resulting scorch height predictions are circled in figure 7B. Notice where those three values appear on the table in figure 5.

When SCORCH is used independently, flame length is an input value. When SCORCH is linked to DIRECT (fig. 3), flame length is calculated. SCORCH can be linked to DIRECT when the steady-state assumptions (Part 1, p. 9) are appropriate. SCORCH can be used independently when the flame length is controlled by the pattern of ignition.

Effective windspeed is used in the calculation of flame length in DIRECT (Part 1, p. 16). Midflame windspeed is used in the scorch height calculation in SCORCH. The DIRECT run in figure 8A illustrates that the effective windspeed for flanking and backing fires (spread directions 90 and 180 degrees) is much less than for the head fire (spread direction 0 degrees). Midflame windspeed and calculated flame lengths in figure 8B are carried over for the scorch height calculations shown in figure 8C. For the head fire, the increasing flame lengths easily offset the flattening effect of wind, and scorch height increases. But the low flame lengths for the flanking and backing fires are tilted enough by the midflame wind that the scorch height decreases.

```
SCORCH
 1--AMBIENT AIR TEMP, F        75.0
 2--FLAME LENGTH, FT            1.0    2.0    3.0    4.0    5.0    6.0    7.0
 3--MIDFLAME WINDSPEED, MI/H     .0    1.0    2.0    3.0    4.0    5.0    6.0
```

CROWN SCORCH HEIGHT, FT (V4.0)							
FLAME LENGTH (FT)	MIDFLAME WINDSPEED, MI/H 0.	1.	2.	3.	4.	5.	6.
1.	3.	3.	2.	1.	1.	1.	0.
2.	8.	8.	7.	6.	5.	3.	3.
3.	15.	15.	14.	13.	11.	9.	7.
4.	23.	23.	22.	21.	18.	16.	14.
5.	32.	32.	31.	30.	27.	25.	22.
6.	41.	41.	41.	40.	37.	34.	31.
7.	52.	52.	51.	50.	48.	45.	42.

Figure 5—Example independent SCORCH run. Note that for a fixed flame length, as windspeed increases, crown scorch height decreases.

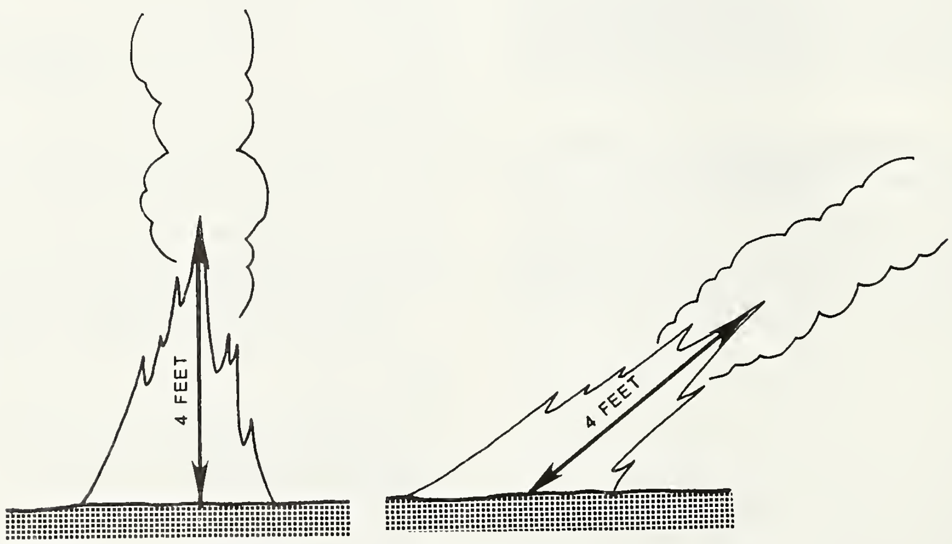


Figure 6—A 4-foot flame with no wind results in higher crown scorch height than a 4-foot flame which is flattened by the wind.

```
DIRECT
 1--FUEL MODEL                   2 -- TIMBER (GRASS AND UNDERSTORY)
 2--1-HR FUEL MOISTURE, %       4.0   6.0   8.0  10.0  12.0
 3--10-HR FUEL MOISTURE, %      6.0
 4--100-HR FUEL MOISTURE, %     6.0
 5--LIVE HERBACEOUS MOIS, %   200.0
 7--MIDFLAME WINDSPEED, MI/H     .0   1.0   2.0   3.0   4.0   5.0   6.0
 8--TERRAIN SLOPE, %             .0
 9--DIRECTION OF WIND VECTOR     .0
10--DIRECTION OF SPREAD          .0  (DIRECTION OF MAX SPREAD)
    CALCULATIONS
     DEGREES CLOCKWISE
      FROM THE WIND VECTOR
```

A

```
=================================================================
FLAME LENGTH, FT                                           (V4.0)
=================================================================
```

1-HR MOIS (%)	MIDFLAME WIND, MI/H 0.	1.	2.	3.	4.	5.	6.
4.	1.7	2.2	3.0	4.0	5.0	5.9	6.8
6.	1.5	2.0	2.8	3.7	4.5	5.4	6.2
8.	1.4	1.9	2.7	3.5	4.3	5.1	5.9
10.	1.3	1.7	2.5	3.2	4.0	4.7	5.5
12.	1.1	1.4	2.0	2.7	3.3	4.0	4.6

```
SCORCH-LINKED-TO-DIRECT
 1--AMBIENT AIR TEMP, F        75.0
 2--FLAME LENGTH, FT           OUTPUT FROM DIRECT. RANGE =    1.1 TO    6.8
 3--MIDFLAME WINDSPEED, MI/H   SAVED FROM DIRECT.  RANGE =     .0 TO    6.0
```

B

```
=================================================================
CROWN SCORCH HEIGHT, FT                                    (V4.0)
=================================================================
```

1-HR MOIS (%)	MIDFLAME WIND, MI/H 0.	1.	2.	3.	4.	5.	6.
4.	6.	9.	15.	21.	27.	33.	39.
6.	6.	8.	13.	18.	23.	28.	34.
8.	5.	8.	12.	16.	21.	26.	30.
10.	5.	7.	10.	14.	18.	22.	26.
12.	4.	5.	8.	10.	13.	16.	18.

Figure 7—SCORCH linked to DIRECT. Three combinations of 1-hour moisture and windspeed give predicted flame lengths of 4 feet as indicated in 7A. The corresponding scorch height predictions are given in 7B.

```
DIRECT
 1--FUEL MODEL                      7 -- SOUTHERN ROUGH
 2--1-HR FUEL MOISTURE, %       10.0
 3--10-HR FUEL MOISTURE, %      10.0
 4--100-HR FUEL MOISTURE, %     10.0
 6--LIVE WOODY MOISTURE, %     150.0
 7--MIDFLAME WINDSPEED, MI/H      .0   2.0   4.0   6.0
 8--TERRAIN SLOPE, %              .0
 9--DIRECTION OF WIND VECTOR      .0
10--DIRECTION OF SPREAD           .0  90.0 180.0
    CALCULATIONS
     DEGREES CLOCKWISE
      FROM THE WIND VECTOR
```

A

```
==================================================================
EFFECTIVE WINDSPEED, MI/H                                  (V4.0)
==================================================================
MIDFLAME I       SPREAD DIRECTION, DEG
  WIND   I
         I     0.     90.    180.
 (MI/H)  I--------------------------------------------------------
         I
  0.     I     .0      .0      .0
         I
  2.     I    2.0      .4      .0
         I
  4.     I    4.0      .6      .1
         I
  6.     I    6.0      .6      .1
```

B

```
==================================================================
FLAME LENGTH, FT                                           (V4.0)
==================================================================
MIDFLAME I       SPREAD DIRECTION, DEG
  WIND   I
         I     0.     90.    180.
 (MI/H)  I--------------------------------------------------------
         I
  0.     I    1.2     1.2     1.2
         I
  2.     I    2.8     1.5     1.2
         I
  4.     I    4.1     1.6     1.2
         I
  6.     I    5.3     1.7     1.2
```

```
SCORCH-LINKED-TO-DIRECT
 1--AMBIENT AIR TEMP, F        80.0
 2--FLAME LENGTH, FT           OUTPUT FROM DIRECT. RANGE =    1.2 TO    5.3
 3--MIDFLAME WINDSPEED, MI/H   SAVED FROM DIRECT.  RANGE =     .0 TO    6.0
```

C

```
==================================================================
CROWN SCORCH HEIGHT, FT                                    (V4.0)
==================================================================
  MIDFLAME   I       SPREAD DIRECTION, DEG
   WIND      I
             I     0.     90.    180.
  (MI/H)     I----------------------------------------------------
             I
   0.        I     4.      4.      4.
             I
   2.        I    14.      5.      3.
             I
   4.        I    21.      3.      2.
             I
   6.        I    26.      2.      1.
```

Figure 8—SCORCH linked to DIRECT. SCORCH uses midflame windspeed rather than effective windspeed.

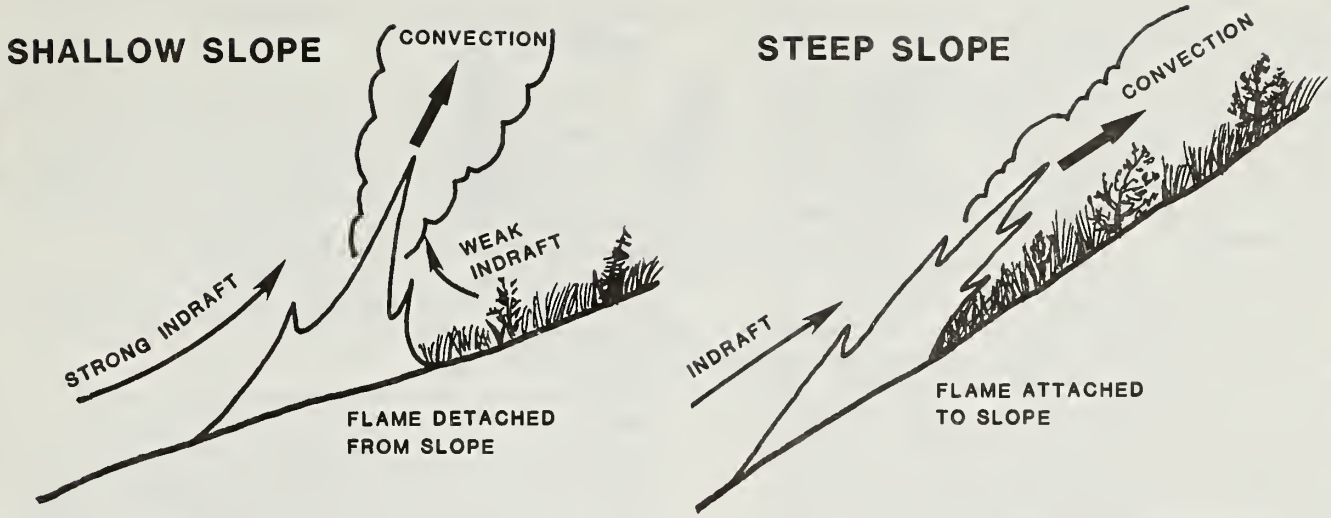


Figure 9—Flame detached from a shallow slope and flames attached to a steep slope.

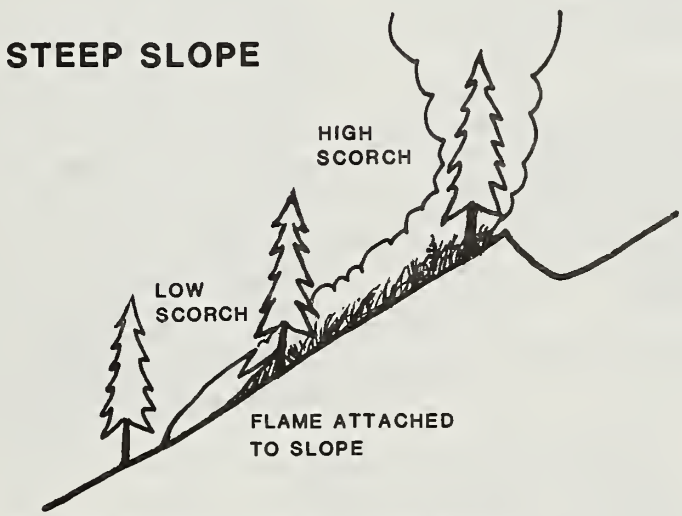


Figure 10—Scorching conditions on a steep slope.

The scorch height model was developed for flat ground. It should be used on slopes only with care. As pointed out in the previous example, the scorch height calculations use midflame windspeed, not effective windspeed. If SCORCH is used when percentage of slope is greater than zero, the slope is essentially ignored except in the effect that it has on the flame length calculations in DIRECT. SCORCH uses midflame windspeed as if the fire were on flat ground.

When using scorch height predictions in mountainous terrain, one must realize that the flame may or may not attach itself to the slope. When it does attach, the hot convective gases and smoke flow up the slope close to the surface rather than rising vertically as shown in figure 9. As stated by Rothermel (1985): "If an overstory of trees is present, the scorch height of trees on a steep slope will be affected. Attachment of the flame to the slope will reduce the scorch height in trees above the flames from what would be expected on level ground where the flames stand vertically. But further up the slope at a ridge line where the convection column breaks from the surface and rises, the concentration of hot gases will scorch higher than expected on the flat." (See fig. 10.) Rothermel further points out that there is no definitive research on the problem of flame attachment. It appears from both lab work and discussions with users that the flame becomes attached near 50 percent slope when there is no prevailing wind.

Care should be taken in applying the scorch height predictions outside of the range of conditions for the 13 test fires used in developing the model. Fireline intensities for those fires were from 19 to 363 Btu/ft/s, which according to the equations used in BEHAVE, convert to flame lengths of 1.8 to 6.8 feet. The scorch heights were

from 6.5 to 56 feet. Temperatures were 73 to 88 °F and midflame windspeeds were 1.5 to 3 mi/h. According to Van Wagner (1973): "Since scorch height for the present set of fires is so well correlated with fire intensity alone, there is not much room for improvement by adding the effects of air temperature and wind .... If air temperature or wind differ markedly from average, then their additional effects may be tentatively estimated from the theory presented."

Other limitations of SCORCH are related to the model that is used to calculate flame length in DIRECT. In developing the crown scorch model, Van Wagner calculated fireline intensity from measurements of rate of spread and of fuel weight before and after burning. In BEHAVE, we use calculated flame length and fireline intensity as described on p. 10-11 of Part 1. This calculation is weighted to the fine fuels and does not include larger fuels that burn after the flaming front has passed. An alternative to using calculated flame length is to use SCORCH independent of DIRECT and enter flame length directly.

The models in DIRECT also assume that fuels are uniform and continuous. SCORCH then gives average values over an area, although variation within a single fire may be considerable.

As with all mathematical models that are used for fire behavior prediction, the scorch height model has limitiations. Even though fire managers are aware of those limitations, they use it frequently in prescribed fire planning. SCORCH was added to BEHAVE because of overwhelming user request. The appeal is that it is a simple model with few inputs. It gives a quantitative link between fire behavior and fire effects.

TREE MORTALITY LEVEL (MORTALITY)

The MORTALITY module of the FIRE1 program predicts percentage of tree mortality from scorch height, tree height, crown ratio, and bark thickness (which can be determined from tree species and tree diameter). It can be used in designing fire prescriptions that achieve acceptable tree survival. As shown in figure 3, MORTALITY can be used as an independent module. It can also be linked to SCORCH, which in turn can either be used independently or linked to DIRECT as described in the previous section.

The model was developed by Ryan and Reinhardt (1988). Formulation for managers including a nomogram and discussion of applications is given in Reinhardt and Ryan (1988). The model is based on tree mortality data taken on 43 prescribed fires in four Western States. This included 2,356 individual trees and seven western conifer species. Mortality was monitored for at least 2 years following the fire.

The model is based on the assumption that trees of different species are similar in their response to a given level of injury and that the level of damage depends on the fire and on tree characteristics (bark thickness, tree height, crown ratio). The basic model in MORTALITY calculates percentage of mortality from bark thickness and percentage of crown volume scorched. In order to make the model more useful as a predictive tool, bark thickness can be either entered directly or determined by tree diameter and species, and percentage of crown volume scorched is calculated from scorch height, tree height, and crown ratio. The relationship among the input values, intermediate values, and percentage of mortality is shown in figure 11. An illustration of several crown ratio values is shown in figure 12.

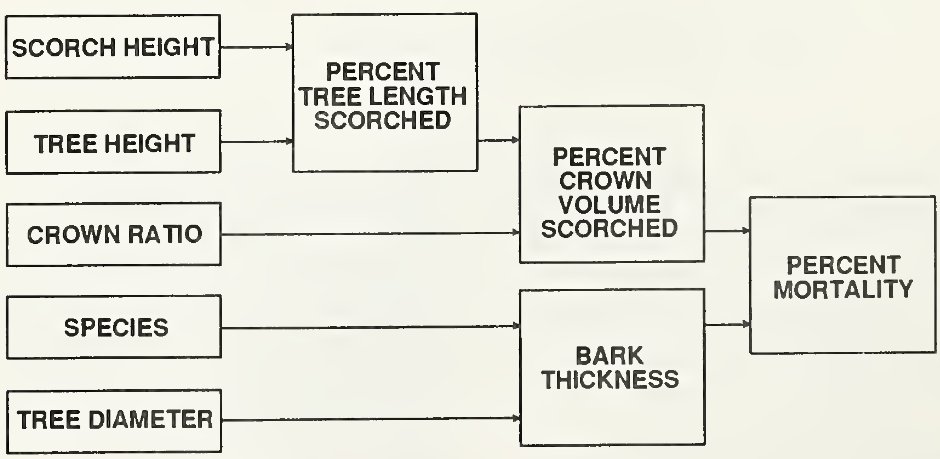


Figure 11—MORTALITY module user input, intermediate values, and final result.

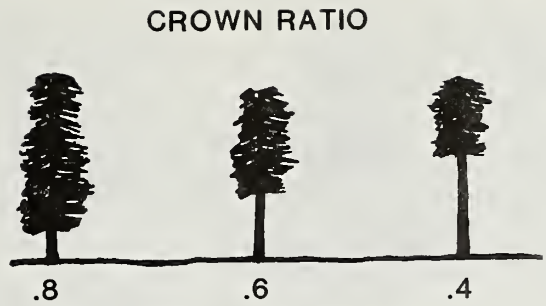


Figure 12—Illustration of three crown ratio values. Crown ratio is an input to MORTALITY.

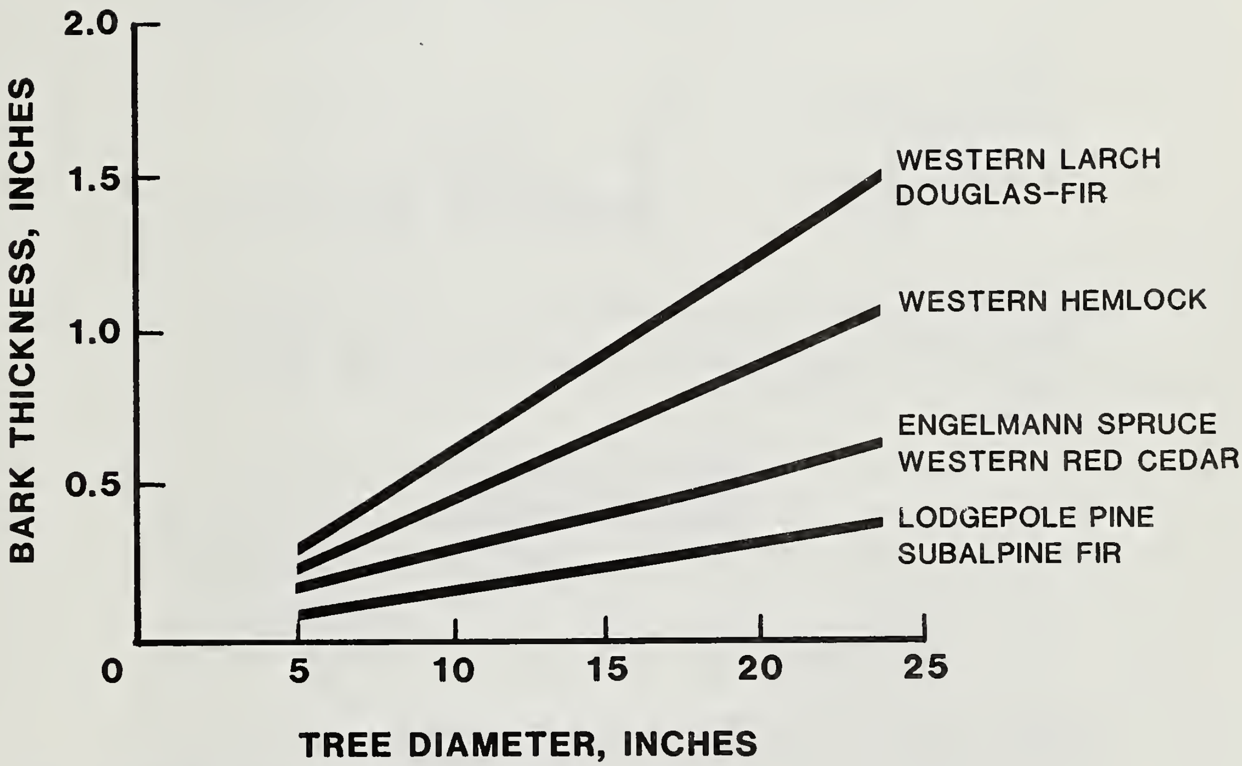


Figure 13—Bark thickness is estimated from tree diameter and species.

The model assumes that the amount of cambium damage is dependent on bark thickness. Bark thickness-tree diameter relationships for the species included in the study are given in figure 13. Only these are included in MORTALITY because the model has not yet been tested on other species. But with this in mind, you can choose the species with the bark thickness relationship that best fits the species you are concerned with or you can enter bark thickness directly.

Mortality predictions can be applied either to a stand or to an individual tree. A prediction of 30 percent mortality means that if 100 similar trees are subjected to the same fire, 30 of them are expected to die. Each tree either lives or dies. There is a 30 percent probability that an individual tree will die.

The basic assumptions of the model must be kept in mind when applying predictions of mortality to a specific area. "The model has an underlying assumption of a fire of average duration. Fires of very long duration will kill cambium through even the thickest bark, and will result in higher than predicted mortality. Thick layers of dry duff may result in long periods of smoldering even after the fire has moved through the area. Heavy concentrations of logs near trees will also result in extended duration of burning and a corresponding underprediction of mortality" (Reinhardt and Ryan 1988). On the other hand, mortality may be overpredicted if fuel is very light or patchy.

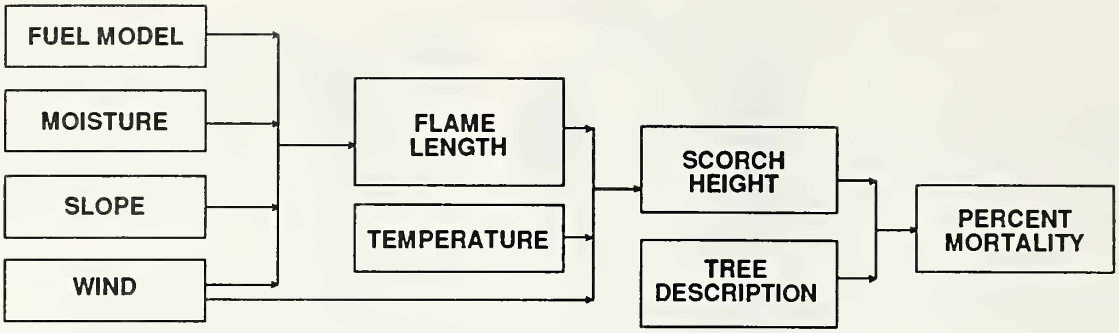


Figure 14—Information flow in MORTALITY linked to DIRECT and SCORCH. When SCORCH is linked to MORTALITY, flame length is input rather than calculated. When MORTALITY is used as an independent module, scorch height is input rather than calculated.

```
MORTALITY
 1--SCORCH HEIGHT, FT           20.0
 2--TREE HEIGHT, FT             40.0  60.0  80.0 100.0
 3--CROWN RATIO                   .9
 4--BARK THICKNESS, IN            .2    .3    .4    .5    .6
      FROM: SPECIES              3=ENGELMANN SPRUCE, WESTERN RED CEDAR
            DBH, IN              5.0  10.0  15.0  20.0  25.0


==================================================================
MORTALITY LEVEL, %                                          (V4.0)
==================================================================
  TREE   I       TREE DBH, IN
 HEIGHT  I
         I     5.    10.    15.    20.    25.
  (FT)   I---------------------------------------------------------
         I
   40.   I    96.    94.    90.    86.    81.
         I
   60.   I    85.    77.    69.    59.    49.
         I
   80.   I    75.    65.    55.    44.    35.
         I
  100.   I    70.    59.    48.    38.    29.
```

Figure 15—Independent MORTALITY run. A range of values is used for tree heights and diameters; scorch height is set to a constant value. Unrealistic combinations of tree height and diameter have been crossed off.

The MORTALITY module can be used in three ways: independent, linked to SCORCH, or linked to DIRECT and SCORCH as shown in figure 3. The choice depends on the application and on available information. Scorch height can be either entered directly (MORTALITY independent) or calculated by SCORCH. Flame length can be either entered directly (SCORCH-MORTALITY link) or calculated by DIRECT (DIRECT-SCORCH-MORTALITY link).

DIRECT-SCORCH-MORTALITY link information is shown in figure 14. DIRECT calculates flame length from fuel model, moisture, wind, and slope. SCORCH uses flame length and wind from DIRECT and ambient temperature to calculate crown scorch height. MORTALITY then uses scorch height and a description of the tree to calculate mortality. This option can be used if a prediction of the level of mortality is based on predicted fire behavior. The assumptions of the models in DIRECT and SCORCH must be met, most notably the steady-state assumption for the flame length calculation (Part 1, p. 9). If flame length is controlled by the pattern of ignition or if flame length is observed, then the SCORCH-MORTALITY link option can be used, allowing you to input flame length directly. If conditions violate the assumptions of the scorch height model (for example steep slopes), or if observed scorch height is available, then MORTALITY can be used as an independent module.

A run of MORTALITY as an independent module is shown in figure 15. This example is for a range of tree heights and tree diameters. Scorch height and crown ratio are held constant. Mortality level ranges from 29 to 96 percent. Some of the combinations of tree heights and diameters are unrealistic. Rather than setting arbitrary cutoff values, we let you make the decision and cross off values as we have done in figure 15.

Figure 16 gives an example of MORTALITY linked to SCORCH. Scorch height is calculated for a range of flame lengths. Mortality level is then calculated for trees of a specified height, crown ratio, species, and diameter.

Figure 17 is an example of the complete DIRECT-SCORCH-MORTALITY link. In this case, flame length is calculated for a range of windspeeds. SCORCH gives the corresponding scorch height values, and MORTALITY gives percentage of mortality expected under these conditions.

```
SCORCH
 1--AMBIENT AIR TEMP, F ----   80.0
 2--FLAME LENGTH, FT -------    2.0    4.0    6.0    8.0   10.0
 3--MIDFLAME WINDSPEED, MI/H    2.0

              (V4.0)
          FLAME    I     CROWN
          LENGTH   I    SCORCH
                   I    HEIGHT
           (FT)    I     (FT)
                   I
           2.0     I       8.
                   I
           4.0     I      24.
                   I
           6.0     I      44.
                   I
           8.0     I      67.
                   I
          10.0     I      94.

MORTALITY-LINKED-TO-SCORCH
 1--SCORCH HEIGHT, FT ------    OUTPUT FROM SCORCH. RANGE =    8. TO    94.
 2--TREE HEIGHT, FT --------   80.0
 3--CROWN RATIO ------------     .8
 4--BARK THICKNESS, IN -----    1.3
      FROM: SPECIES             1=WESTERN LARCH, DOUGLAS-FIR
            DBH, IN            20.0

      (V4.0)
FLAME    I   MORTALITY      CROWN
LENGTH   I     LEVEL        VOLUME
         I                  SCORCH
 (FT)    I      (%)          (%)
         I
  2.0    I        5.          0.
         I
  4.0    I        7.         24.
         I
  6.0    I       41.         69.
         I
  8.0    I       89.         96.
         I
 10.0    I       92.        100.
```

Figure 16—MORTALITY linked to SCORCH. A range of flame lengths is input into SCORCH.

```
DIRECT
 1--FUEL MODEL                       2 -- TIMBER (GRASS AND UNDERSTORY)
 2--1-HR FUEL MOISTURE, %          4.0
 3--10-HR FUEL MOISTURE, %         6.0
 4--100-HR FUEL MOISTURE, %        6.0
 5--LIVE HERBACEOUS MOIS, %      200.0
 7--MIDFLAME WINDSPEED, MI/H       3.0    4.0    5.0
 8--TERRAIN SLOPE, %                .0
 9--DIRECTION OF WIND VECTOR        .0
10--DIRECTION OF SPREAD             .0   (DIRECTION OF MAX SPREAD)
    CALCULATIONS
     DEGREES CLOCKWISE
      FROM THE WIND VECTOR


      (V4.0)
MIDFLAME I RATE OF  HEAT PER   FIRELINE   FLAME   REACTION   EFFECT.
  WIND   I SPREAD  UNIT AREA  INTENSITY  LENGTH  INTENSITY  WIND
         I
 (MI/H)  I (CH/H)  (BTU/SQFT) (BTU/FT/S)  (FT)  (BTU/SQFT/M) (MI/H)
         I
   3.    I   13.       492.       116.     4.0     3567.      3.0
         I
   4.    I   20.       492.       184.     5.0     3567.      4.0
         I
   5.    I   30.       492.       268.     5.9     3567.      5.0


SCORCH-LINKED-TO-DIRECT
 1--AMBIENT AIR TEMP, F        75.0
 2--FLAME LENGTH, FT           OUTPUT FROM DIRECT. RANGE =    4.0 TO    5.9
 3--MIDFLAME WINDSPEED, MI/H   SAVED FROM DIRECT.  RANGE =    3.0 TO    5.0


               (V4.0)
         MIDFLAME I    CROWN
           WIND   I   SCORCH
                  I   HEIGHT
          (MI/H)  I    (FT)
                  I
           3.     I     21.
                  I
           4.     I     27.
                  I
           5.     I     33.

MORTALITY-LINKED-TO-DIRECT-AND-SCORCH
 1--SCORCH HEIGHT, FT          OUTPUT FROM SCORCH. RANGE =   21. TO   33.
 2--TREE HEIGHT, FT            50.0
 3--CROWN RATIO                  .5
 4--BARK THICKNESS, IN           .1
      FROM: SPECIES             4=LODGEPOLE PINE, SUBALPINE FIR
            DBH, IN            10.0


      (V4.0)
MIDFLAME I   MORTALITY      CROWN
  WIND   I     LEVEL        VOLUME
         I                  SCORCH
 (MI/H)  I      (%)          (%)
         I
   3.    I      68.            0.
         I
   4.    I      71.           15.
         I
   5.    I      92.           55.
```

Figure 17—MORTALITY linked to DIRECT and SCORCH. Flame length is calculated for a range of windspeeds in DIRECT.

MAXIMUM SPOTTING DISTANCE FROM WIND-DRIVEN SURFACE FIRES (SPOT)

The SPOT module of the FIRE1 program predicts the maximum distance that a firebrand will travel from torching trees, a burning pile of debris, or from a wind-driven surface fire. Use of SPOT for torching trees and burning piles is described in Part 1 (p. 47-49). The only change to those options is that additional tree species have been added to the torching tree option: slash pine, longleaf pine, pond pine, shortleaf pine, and loblolly pine (Albini 1979). The option of spotting from wind-driven surface fires (Albini 1983; Chase 1984; Morris 1987) has been added and is described here.

The option of spotting from a wind-driven surface fire can be either an independent SPOT run or linked with DIRECT. Input requirements are flame length, windspeed, and a description of the terrain. In a linked run, flame length and windspeed, are carried over from DIRECT to SPOT.

The basic assumptions that apply to all options of the spotting model are repeated here. The model is designed to predict intermediate-range spotting, not short-range spotting such as debris blowing just across a fire line. We are concerned with spots that occur far enough from the main fire to grow as independent fires. But we are not dealing with the problem of very extreme fire behavior conditions, where spotting is caused by large firebrands (even logs) being carried into the combustion column. Predictions are for **maximum** spotting distance because ideal conditions are assumed. Firebrands are assumed to be sufficiently small to be carried some distance, yet large enough to still be able to start a fire when they reach the ground. The model, however, does not address the problem of firebrands such as eucalyptus bark that literally fly through the air.

The process by which firebrands are transported from wind-driven surface fires is postulated to be that of lofting of particles by line thermals that are generated by variations in the intensity of the fire. The model is based on the assumption that the fire front is approximated by a straight line perpendicular to the direction of the wind. Predictions therefore apply to wind-driven head fires, not flanking or backing fires and not fires whose spread is influenced more by the slope than by the wind.

Use of the predictions of spotting distance from wind-driven surface fires is restricted to cases where there is no overstory. Mean cover height is set to zero. Fires burning under standing timber seldom cause spot fires at any significant distance unless the trees of the overstory become involved in the fire. The overstory is a barrier that intercepts firebrands and also interferes with development of a strong updraft that can lift firebrand particles. Some fuel models ordinarily have overstories, but are sometimes used to represent fuels without overstory cover. For example, fuel model 10 (timber litter and understory) is sometimes used to represent timber harvest debris overgrown with shrubs or other vegetation.

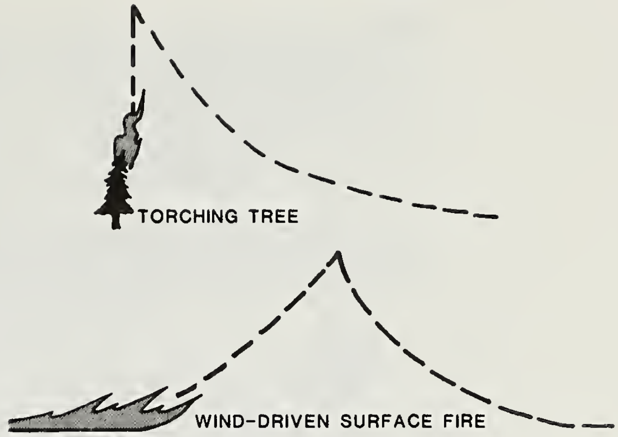


Figure 18—A firebrand from a torching tree or a burning pile is lifted straight up and then carried by the prevailing wind. This is compared to a firebrand from a wind-driven surface fire, which is carried some distance downwind from the firefront where the thermal originated before it is carried by the prevailing wind.

All three spotting source location options use the same method of calculating the distance that a firebrand is carried by the prevailing wind. The difference is in calculating initial lofting height. For the torching tree option, a description of the trees is used to calculate transitory flame characteristics. For the burning pile option, continuous flame height is entered directly. For the wind-driven surface fire option, flame length is used as an indicator of the energy in a thermal from a line fire. When the particle exits the rising thermal, it will be some distance downwind from the firefront where the thermal originated. Figure 18 illustrates the difference in the trajectories of a firebrand from a torching tree and from a wind-driven surface fire.

SPOT is offered both independently and linked to DIRECT as shown in figure 3. The independent option is included to allow the flexibility of examining the spotting distance model on its own. You are allowed to enter any value for the required input as done in figures 19 and 20 described below. But the most common use of the wind-driven surface fire option of SPOT will probably be linked to DIRECT, which calculates flame lengths, as shown in figures 21 and 22. Because flame length is not used in the torching tree or burning pile options, only the wind-driven surface fire option can be linked to DIRECT.

Figure 19 shows independent SPOT runs for two spotting source options: burning pile and wind-driven surface fire. In both cases, the mean cover height is zero. The same range of windspeeds was used in each case. And the same values were used for continuous flame height and for flame length. Notice that the predicted spotting distances are longer for the wind-driven surface fire option. This example is used to point out the difference in continuous flame height from a burning pile of debris and the flame length from a wind-driven surface fire. It also illustrates the effect of the difference in lofting mechanisms.

SPOT

1--FIREBRAND SOURCE--------	2--BURNING PILE						
2--MEAN COVER HEIGHT, FT	.0						
3--20-FOOT WINDSPEED, MI/H	5.0	10.0	15.0	20.0	25.0	30.0	35.0
4--RIDGE/VALLEY ELEVATION DIFFERENCE, FT	.0						
11--CONTINUOUS FLAME HT, FT	4.0	8.0	12.0	16.0	20.0	24.0	28.0

MAXIMUM SPOTTING DISTANCE, MI (V4.0)

20-FT WINDSPEED (MI/H)	CONTINUOUS FLAME HEIGHT, FT 4.	8.	12.	16.	20.	24.	28.
5.	.0	.1	.1	.1	.1	.1	.1
10.	.1	.1	.1	.2	.2	.2	.2
15.	.1	.2	.2	.2	.3	.3	.3
20.	.1	.2	.3	.3	.4	.4	.5
25.	.2	.3	.3	.4	.5	.5	.6
30.	.2	.3	.4	.5	.6	.6	.7
35.	.2	.4	.5	.6	.7	.7	.8

SPOT

1--FIREBRAND SOURCE--------	3--WIND-DRIVEN SURFACE FIRE						
2--MEAN COVER HEIGHT, FT	.0						
3--20-FOOT WINDSPEED, MI/H	5.0	10.0	15.0	20.0	25.0	30.0	35.0
4--RIDGE/VALLEY ELEVATION DIFFERENCE, FT	.0						
12--FLAME LENGTH, FT	4.0	8.0	12.0	16.0	20.0	24.0	28.0

MAXIMUM SPOTTING DISTANCE, MI (V4.0)

20-FT WINDSPEED (MI/H)	FLAME LENGTH, FT 4.	8.	12.	16.	20.	24.	28.
5.	.1	.2	.2	.2	.3	.3	.4
10.	.2	.2	.3	.4	.5	.5	.6
15.	.2	.3	.4	.5	.6	.7	.8
20.	.2	.4	.5	.6	.7	.8	.9
25.	.3	.5	.6	.7	.9	1.0	1.1
30.	.3	.5	.7	.8	1.0	1.1	1.2
35.	.4	.6	.8	.9	1.1	1.2	1.4

Figure 19—Independent SPOT runs for two spotting source options: burning pile and wind-driven surface fire.

A

```
SPOT
 1--FIREBRAND SOURCE--------     3--WIND-DRIVEN SURFACE FIRE
 2--MEAN COVER HEIGHT, FT         .0
 3--20-FOOT WINDSPEED, MI/H      5.0  10.0  15.0  20.0  25.0  30.0  35.0
 4--RIDGE/VALLEY ELEVATION
          DIFFERENCE, FT          0. 1000. 2000. 3000. 4000.
 5--RIDGE/VALLEY HORIZONTAL
          DISTANCE, MI           1.0
 6--SPOTTING SOURCE LOCATION     0.-- MIDSLOPE, WINDWARD SIDE
12--FLAME LENGTH, FT            20.0
```

MAXIMUM SPOTTING DISTANCE, MI (V4.0)

20-FT WINDSPEED (MI/H)	RIDGE/VALLEY ELEVATIONAL DIFFERENCE, FT 0.	1000.	2000.	3000.	4000.
5.	.3	.3	.3	.3	.4
10.	.5	.5	.5	.6	.7
15.	.6	.7	.7	.8	.9
20.	.7	.8	.9	.9	1.0
25.	.9	.9	1.0	1.1	1.1
30.	1.0	1.0	1.1	1.2	1.2
35.	1.1	1.1	1.2	1.2	1.3

B

```
SPOT
 1--FIREBRAND SOURCE--------     3--WIND-DRIVEN SURFACE FIRE
 2--MEAN COVER HEIGHT, FT         .0
 3--20-FOOT WINDSPEED, MI/H      5.0  10.0  15.0  20.0  25.0  30.0  35.0
 4--RIDGE/VALLEY ELEVATION
          DIFFERENCE, FT          0. 1000. 2000. 3000. 4000.
 5--RIDGE/VALLEY HORIZONTAL
          DISTANCE, MI           1.0
 6--SPOTTING SOURCE LOCATION     2.-- MIDSLOPE, LEEWARD SIDE
12--FLAME LENGTH, FT            20.0
```

MAXIMUM SPOTTING DISTANCE, MI (V4.0)

20-FT WINDSPEED (MI/H)	RIDGE/VALLEY ELEVATIONAL DIFFERENCE, FT 0.	1000.	2000.	3000.	4000.
5.	.3	.3	.3	.3	.3
10.	.5	.4	.4	.4	.4
15.	.6	.6	.5	.5	.5
20.	.7	.7	.7	.6	.6
25.	.9	.8	.8	.7	.7
30.	1.0	.9	.9	.8	.8
35.	1.1	1.0	1.0	.9	.8

Figure 20—Independent SPOT run for two spotting source locations.

```
DIRECT
 1--FUEL MODEL                      6 -- DORMANT BRUSH, HARDWOOD SLASH
 2--1-HR FUEL MOISTURE, %         8.0
 3--10-HR FUEL MOISTURE, %       10.0
 4--100-HR FUEL MOISTURE, %      10.0
 7--MIDFLAME WINDSPEED, MI/H      5.0  10.0  15.0  20.0  25.0
 8--TERRAIN SLOPE, %               .0
 9--DIRECTION OF WIND VECTOR       .0
10--DIRECTION OF SPREAD            .0  (DIRECTION OF MAX SPREAD)
    CALCULATIONS
     DEGREES CLOCKWISE
      FROM THE WIND VECTOR
```

(V4.0)

MIDFLAME WIND (MI/H)	I	RATE OF SPREAD (CH/H)	HEAT PER UNIT AREA (BTU/SQFT)	FIRELINE INTENSITY (BTU/FT/S)	FLAME LENGTH (FT)	REACTION INTENSITY (BTU/SQFT/M)	EFFECT. WIND (MI/H)
5.	I	29.	436.	235.	5.5	1777.	5.0
10.	I	72.	436.	576.	8.4	1777.	10.0
15.	I	123.	436.	983.	10.7	1777.	15.0
20.	I	159.	436.	1268.	12.0	1777.	18.2*
25.	I	159.	436.	1268.	12.0	1777.	18.2*

* MEANS YOU HIT THE WIND LIMIT.

```
SPOT-LINKED-TO-DIRECT
 1--FIREBRAND SOURCE--------       3--WIND-DRIVEN SURFACE FIRE
 2--MEAN COVER HEIGHT, FT           .0
 3--20-FOOT WINDSPEED, MI/H       12.5  25.0  37.5  50.0  62.5
      FROM MIDFLAME WIND =         5.0  10.0  15.0  20.0  25.0
      & EXPOSED FUEL WAF =          .4
 4--RIDGE/VALLEY ELEVATION
           DIFFERENCE, FT           .0
12--FLAME LENGTH, FT               OUTPUT FROM DIRECT. RANGE=    5.5 TO    12.0
```

(V4.0)

MIDFLAME WIND (MI/H)	I	MAXIMUM SPOTTING DISTANCE (MI)
5.	I	.2
10.	I	.5
15.	I	.7
20.	I	1.0
25.	I	1.1

Figure 21—SPOT linked to DIRECT. The maximum effective windspeed is used in the flame length calculations. The actual windspeed is used in the spotting distance calculations.

A

```
DIRECT
 1--FUEL MODEL                    4 -- CHAPARRAL, 6 FT (180 CM)
 2--1-HR FUEL MOISTURE, %       5.0  10.0  15.0
 3--10-HR FUEL MOISTURE, %      6.0
 4--100-HR FUEL MOISTURE, %     6.0
 6--LIVE WOODY MOISTURE, %    150.0
 7--MIDFLAME WINDSPEED, MI/H   10.0  20.0  30.0
 8--TERRAIN SLOPE, %           20.0
 9--DIRECTION OF WIND VECTOR     .0
     DEGREES CLOCKWISE
      FROM UPHILL
10--DIRECTION OF SPREAD          .0  (DIRECTION OF MAX SPREAD)
    CALCULATIONS
     DEGREES CLOCKWISE
      FROM UPHILL

==================================================================
FLAME LENGTH, FT                                            (V4.0)
==================================================================
  1-HR   I       MIDFLAME WIND, MI/H
  MOIS   I
         I   10.    20.    30.
  (%)    I---------------------------------------------------------
         I
  5.     I  27.1   42.0   54.6
         I
 10.     I  24.4   37.8   49.1
         I
 15.     I  11.2   17.5   22.7


SPOT-LINKED-TO-DIRECT
 1--FIREBRAND SOURCE--------    3--WIND-DRIVEN SURFACE FIRE
 2--MEAN COVER HEIGHT, FT        .0
 3--20-FOOT WINDSPEED, MI/H    16.7  33.3  50.0
      FROM MIDFLAME WIND =     10.0  20.0  30.0
      & EXPOSED FUEL WAF =       .6
 4--RIDGE/VALLEY ELEVATION
           DIFFERENCE, FT    1000.0
 5--RIDGE/VALLEY HORIZONTAL
           DISTANCE, MI         1.0
 6--SPOTTING SOURCE LOCATION    0.-- MIDSLOPE, WINDWARD SIDE
12--FLAME LENGTH, FT            OUTPUT FROM DIRECT. RANGE=   11.2 TO   54.6


==================================================================
MAXIMUM SPOTTING DISTANCE, MI                               (V4.0)
==================================================================
    1-HR     I       MIDFLAME WIND, MI/H
    MOIS     I
             I   10.    20.    30.
    (%)      I-----------------------------------------------------
             I
     5.      I      .9    1.8    2.8
             I
    10.      I      .8    1.7    2.6
             I
    15.      I      .5    1.0    1.5
```

Figure 22—SPOT linked to DIRECT. The direction of the wind vector is upslope in figure 22A and downslope in 22B.

B

```
DIRECT
 1--FUEL MODEL                    4 -- CHAPARRAL, 6 FT (180 CM)
 2--1-HR FUEL MOISTURE, %        5.0  10.0  15.0
 3--10-HR FUEL MOISTURE, %       6.0
 4--100-HR FUEL MOISTURE, %      6.0
 6--LIVE WOODY MOISTURE, %     150.0
 7--MIDFLAME WINDSPEED, MI/H    10.0  20.0  30.0
 8--TERRAIN SLOPE, %            20.0
 9--DIRECTION OF WIND VECTOR   180.0
     DEGREES CLOCKWISE
      FROM UPHILL
10--DIRECTION OF SPREAD         DIRECTION OF MAXIMUM SPREAD
     CALCULATIONS                 TO  BE CALCULATED
     DEGREES CLOCKWISE
      FROM UPHILL


==================================================================
FLAME LENGTH, FT                                            (V4.0)
==================================================================
  1-HR    I       MIDFLAME WIND, MI/H
  MOIS    I
          I    10.     20.     30.
  (%)     I-------------------------------------------------------
          I
   5.     I   26.5    41.7    54.4
          I
  10.     I   23.8    37.5    48.9
          I
  15.     I   11.0    17.3    22.6


SPOT-LINKED-TO-DIRECT
 1--FIREBRAND SOURCE--------      3--WIND-DRIVEN SURFACE FIRE
 2--MEAN COVER HEIGHT, FT          .0
 3--20-FOOT WINDSPEED, MI/H      16.7  33.3  50.0
      FROM MIDFLAME WIND =       10.0  20.0  30.0
      & EXPOSED FUEL WAF =         .6
 4--RIDGE/VALLEY ELEVATION
           DIFFERENCE, FT      1000.0
 5--RIDGE/VALLEY HORIZONTAL
           DISTANCE, MI           1.0
 6--SPOTTING SOURCE LOCATION      2.-- MIDSLOPE, LEEWARD SIDE
12--FLAME LENGTH, FT              OUTPUT FROM DIRECT. RANGE=   11.0 TO   54.4

==================================================================
MAXIMUM SPOTTING DISTANCE, MI                               (V4.0)
==================================================================
    1-HR      I       MIDFLAME WIND, MI/H
    MOIS      I
              I    10.     20.     30.
    (%)       I-------------------------------------------------
              I
     5.       I     .7     1.7     2.7
              I
    10.       I     .7     1.6     2.5
              I
    15.       I     .4      .9     1.5
```

Figure 22 (Con.)

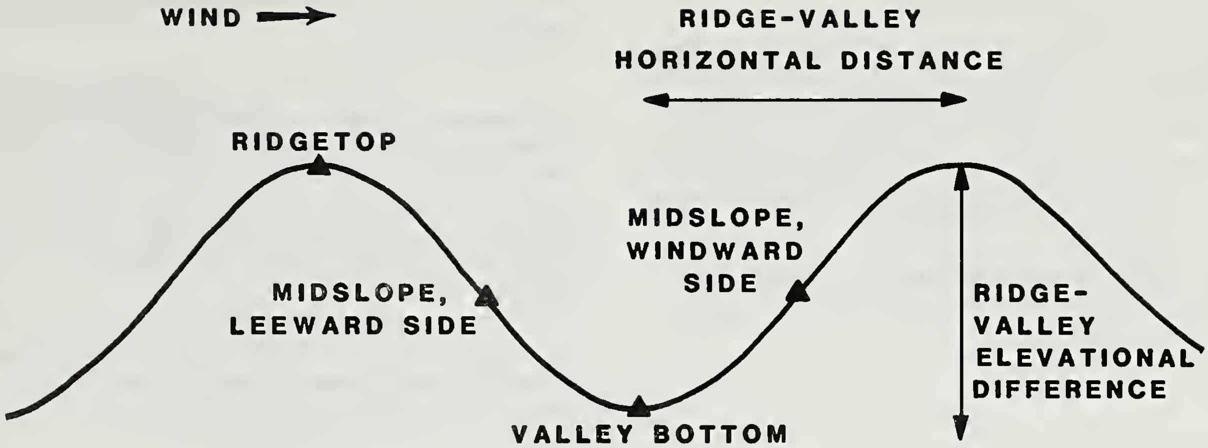


Figure 23—Mountainous terrain and spotting source location for the maximum spotting distance model.

Another use of SPOT as an independent module is to examine the effect of a change in the terrain description and spotting source location as shown in figure 20. Flame length is assigned a constant value of 20 feet. The spotting source location is midslope on the windward side for figure 20A and midslope on the leeward side for figure 20B. Recall that the spotting distance model defines the terrain with the smooth curve shown in figure 23.

Because predictions are for spotting from the head of a wind-driven fire, the link to DIRECT is allowed only when calculations are done for the direction of maximum spread as specified in line 10 input to DIRECT. In addition, spotting distance predictions are not given when the difference between the direction of the wind vector and the calculated direction of maximum spread is more than 30 degrees. In that case the fire no longer meets the assumptions of a wind-driven head fire. The direction of spread of the head fire is significantly different from the direction of the wind vector only for low windspeeds and steep slope.

The windspeed that is required by SPOT is the 20-foot windspeed while the windspeed input into DIRECT is at midflame height. The wind adjustment factor was designed to reduce 20-foot windspeed to midflame windspeed, and use in reverse is not recommended. But this is a no overstory situation and we are not concerned with slope winds. We therefore use the exposed-fuel wind adjustment factor associated with each fuel model (Part 1, p. 36) to convert the midflame windspeed from DIRECT to the 20-foot windspeed required by SPOT. As illustrated in figure 21, the list for SPOT linked to DIRECT gives the range of midflame windspeeds carried over from DIRECT, the exposed-fuel wind adjustment factor for the fuel model specified in DIRECT, and the resulting range of 20-foot windspeeds that are used in SPOT. Notice that the wind limit is reached in this example. The maximum effective windspeed of 18.2 mi/h is used in the flame length calculations, while the actual windspeed is carried over to SPOT.

Chaparral often burns under Santa Ana wind conditions, resulting in high-intensity line fires. Figure 22 shows predicted flame lengths and spotting distances for a range of fine dead fuel moistures and midflame windspeeds. In the first example, the wind is blowing upslope and the spotting source is midslope on the windward side. In the second example, wind is blowing downslope and the spotting source is midslope on the leeward side. Flame length and spotting distance predictions are, however, nearly the same. This is a wind-driven fire and the slope has very little effect. You are responsible for the consistency between the slope and wind direction input to DIRECT and the terrain description and spotting source location in SPOT. But do not be overly concerned with it. There is much variability in real world terrain as compared to the smooth curve used in the model (fig. 23). Table output from SPOT can be used to examine the effect of a range of values on the predictions.

The maximum spotting distance predictions can be used for both wildfire and for prescribed fire. About all that can be done about the occurrence of spot fires on wildfires is to predict where they might be and to watch for them. Spot fires beyond the main front can be a major factor in safety considerations and crew placement. In the planning stage of prescribed fire, spotting distance predictions can be used to determine acceptable conditions for executing the burn. Predictions can be used to place holding crews when the burn is conducted.

Albini (1983) points out that "because several elements of the model process are both speculative and not subject to direct validation, these results are to be considered tentative. Field tests of the spotting distance predictions are sought as a means of testing the utility of the model." Keep in mind that these predictions are for **maximum** spotting distances, and that most firebrands are not expected to travel that distance.

MAP DISTANCE (MAP)

MAP is an independent module in the FIRE1 program that translates calculated distances to measurements that can be plotted on a map. These may be spread distance from SIZE, maximum spotting distance from SPOT, or rate of spread from DIRECT or SITE. The map scale can be specified as either representative fraction or as inches per mile or centimeters per kilometer.

Figure 24 shows the equivalent map distance for three values of maximum spotting distance. Figure 25 shows the map spread distance for various values of rate of spread and elapsed time.

SLOPE (SLOPE, PERCENT, AND DEGREES)

A value for slope is used in the spread and intensity calculations in DIRECT and SITE. DIRECT requires direct input of the slope value. SITE either accepts the value directly or offers the option of calculating it from map measurements as described in Part 1, p. 38. We now offer the independent keyword SLOPE in the FIRE1 program for calculating slope value from topographic map measurements.

Calculation of slope steepness is based on map scale, contour interval, and the number of contour intervals over a specified map distance. Figure 26 shows calculated slope values in percentage and then degrees.

```
MAP
 1--MAP SCALE, IN/MI--------     3.00
                                 1:21120
 2--UNITS OPTION------------     2.=SPOT DISTANCE
 4--SPOT DISTANCE, MI            1.0   2.0   3.0


           (V4.0)
  SPOT        I        MAP
DISTANCE      I     SPOT FIRE
              I     DISTANCE
  (MI)        I       (IN)
              I
   1.         I       3.0
              I
   2.         I       6.0
              I
   3.         I       9.0
```

Figure 24—Example MAP run to convert spotting distance to map distance.

```
MAP
 1--MAP SCALE, IN/MI--------     2.00
                                 1:31680
 2--UNITS OPTION------------     3.=RATE OF SPREAD
 5--RATE OF SPREAD, CH/H        20.0  30.0  40.0  50.0
 6--ELAPSED TIME, HR              .5   1.0   1.5   2.0


=================================================================
MAP SPREAD DISTANCE, IN                                    (V4.0)
=================================================================
  RATE   I        ELAPSED TIME, HR
   OF    I
 SPREAD  I    .5    1.0    1.5    2.0
 (CH/H)  I--------------------------------------------------------
         I
  20.    I    .3     .5     .8    1.0
         I
  30.    I    .4     .8    1.1    1.5
         I
  40.    I    .5    1.0    1.5    2.0
         I
  50.    I    .6    1.3    1.9    2.5
```

Figure 25—Example MAP run to convert rate of spread and elapsed time to map distance.

```
SLOPE
 1--MAP SCALE, IN/MI--------     2.64
                                 1:24000
 2--CONTOUR INTERVAL, FT        20.0
 3--MAP DISTANCE, IN              .4
 4--NUMBER CONTOUR INTERVALS    10.0   20.0   30.0   40.0   50.0
```

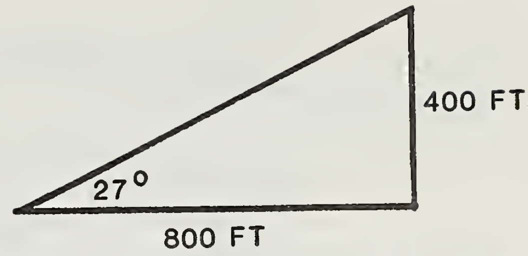
(V4.0)

NUMBER OF CONTOUR INTERVLS	TERRAIN SLOPE (%)	ELEVATION CHANGE (FT)	HORIZONTAL DISTANCE (FT)
10.	25.	200.	800.
20.	50.	400.	800.
30.	75.	600.	800.
40.	100.	800.	800.
50.	125.	1000.	800.

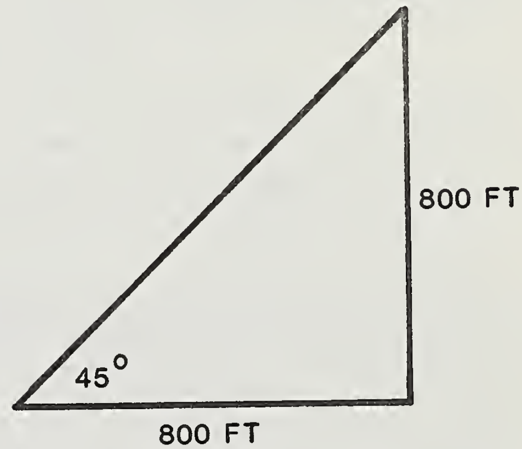
(V4.0)

NUMBER OF CONTOUR INTERVLS	TERRAIN SLOPE (DEG)	ELEVATION CHANGE (FT)	HORIZONTAL DISTANCE (FT)
10.	14.	200.	800.
20.	27.	400.	800.
30.	37.	600.	800.
40.	45.	800.	800.
50.	51.	1000.	800.

Figure 26—Example SLOPE run, first under the mode PERCENT, then under the mode DEGREES.



$$100 \cdot \tan(27^\circ) = 100 \cdot \frac{400}{800} = 50\%$$



$$100 \cdot \tan(45^\circ) = 100 \cdot \frac{800}{800} = 100\%$$

Figure 27—A 27-degree slope is equivalent to a 50-percent slope; 45 degrees is equivalent to 100 percent.

In the earlier version of the program, slope was always specified as percentage. This is the standard in the United States, but some prefer to use degrees. The keywords PERCENT and DEGREES are used to set the mode. The default mode is PERCENT. The mode can be changed at any time, and remains in effect until it is changed again. The keyword DEGREES was entered between the two runs in figure 26.

Notice in figure 26 that a 27-degree slope is equivalent to a 50-percent slope; 45 degrees is equivalent to 100 percent. Those two cases are diagramed in figure 27.

PROBABILITY OF IGNITION (IGNITE)

The IGNITE module of the FIRE2 program allows calculation of probability that a firebrand will ignite forest fuels, given 1-hour fuel moisture, ambient air temperature, and shading of fuels due to cloud and canopy cover. An IGNITE run is shown in figure 28.

As shown in figure 3, IGNITE is an independent module in the FIRE2 program. It is, however, also automatically part of the MOISTURE module, which is described in the next section. Because the input values for IGNITE are already available from MOISTURE, probability of ignition is always given as an output value.

The equation used to calculate probability of ignition was developed by Schroeder (1969). It is based on fuel temperature and moisture content. The method of obtaining fuel temperature is handled differently in the independent module IGNITE than in the automatic probability of ignition calculations in MOISTURE. IGNITE calculations result in the same values as the table given by Rothermel (1983, p. 106). Depending on the shade category, a fixed value is added to air temperature to get fuel temperature. When probability of ignition is calculated as part of MOISTURE, fuel temperature is found using more sophisticated methods that are part of the moisture model (Rothermel and others 1986).

```
IGNITE
 1--DRY BULB TEMPERATURE, F     40.0  60.0  80.0 100.0 120.0
 2--1-HR FUEL MOISTURE, %        2.0   4.0   6.0   8.0  10.0  12.0  14.0
 3--FUEL SHADING, %             40.0


=============================================================
PROBABILITY OF IGNITION, %                             (V4.0)
=============================================================
   DRY      I      1-HR FUEL MOISTURE, %
   BULB     I
   TEMP     I   2.     4.     6.     8.    10.    12.    14.
   (F)      I-------------------------------------------------
            I
  40.0      I   90.    70.    50.    40.    30.    20.    10.
            I
  60.0      I   90.    70.    50.    40.    30.    20.    20.
            I
  80.0      I  100.    80.    60.    40.    30.    20.    20.
            I
 100.0      I  100.    80.    60.    50.    40.    30.    20.
            I
 120.0      I  100.    90.    70.    50.    40.    30.    20.
```

Figure 28—Example IGNITE run.

Probability of ignition is the chance that an ignition will result if a firebrand lands on flammable material and that its heat is efficiently and rapidly transferred to the fuel (Schroeder 1969). That is, for probability of ignition of 80 percent, 80 of 100 firebrands will cause ignitions, all conditions being equal and fitting the assumptions of the model. But the probability that an ember might ignite receptive fuel is only one aspect of the spotting problem. There remain questions on whether firebrands are produced, how many, what size and shape, where they land, and so on. (As described in a previous section, the SPOT module of the FIRE1 program predicts maximum spotting distance.)

Although probability of ignition of 80 percent may not tell you how many spot fires will occur, it is an indication of the severity of the situation. Probability of ignition of 80 percent certainly indicates a more severe situation than probability of ignition of 20 percent. Most mathematical models in BEHAVE give predictions in absolute terms: rate of spread in chains per hour, flame length in feet, spotting distance in miles, and so on. Probability of ignition is a percentage. But there are so many unknowns (as described above) that interpretation must largely be based on your experience. This may be in terms such as "little chance of spot fires," "probable spot fires," or "spot fires likely if firebrands are being generated."

Ignition Component (IC), a component of the National Fire Danger Rating System (Deeming and others 1977), is sometimes confused with probability of ignition. Probability of ignition includes a calculation of the heat of preignition, the net amount of heat necessary to raise the temperature of a fuel particle from its initial temperature to its ignition temperature. The model is also based on the results of a study by Blackmarr (1972), who measured the influence of moisture content on the ignitability of slash pine litter by dropping lighted matches onto fuel beds conditioned to different levels of moisture content.

Ignition Component (IC) was designed for rating fire danger. IC is based on probability of ignition. IC also includes a factor derived from the NFDRS fuel model that makes it a better indicator of human-caused fire occurrence. That factor is based on the finding that incidence of human-caused fires increases with windspeeds over 8 mi/h even though windspeed has nothing to do with the ignition process. This is explained by Haines, Main, and Crosby (1973):

> If a fire goes out quickly, there will have been a fire start, but not necessarily a **reportable** fire. Debris-burning fires offer a good example. If a firebrand from a trash burner ignites dry grass on a Missouri oak-hickory litter area during a calm afternoon, the fire should spread slowly and may be suppressed by the person maintaining the burner. On a windy day, however, the fire may escape and the operator will have to call for the assistance of a fire suppression unit.

The concept of "reportable" fires is important to rating the fire danger for a large area so that the impact on a fire suppression organization can be estimated. On the other hand, for a specific prescribed fire or wildfire, all ignitions are important. We are concerned with the probability that a firebrand will result in an ignition beyond the fire front or control line. Therefore, Ignition Component is used for fire danger rating; probability of ignition is used for fire behavior prediction.

FINE DEAD FUEL MOISTURE (MOISTURE)

The MOISTURE module of the FIRE2 program and the SITE module of the FIRE1 program are both based on the fine dead fuel moisture model (Rothermel and others 1986). Although all fine dead fuels (0- to 1/4-inch diameter) are not technically 1-hour timelag (Anderson 1985), we continue to use the currently accepted naming convention, 1-hour .

SITE allows a single calculation of rate of spread, flame length, and intensity with 1-hour moisture content as an intermediate value (Part 1, p. 8). MOISTURE is used to calculate only 1-hour moisture content, offering both table and graphic output. Because of the similarities between SITE and MOISTURE, the same input/output sheet is used for both. Items that apply only to SITE or to MOISTURE are so noted. (The line numbers for SITE have changed from those given in Part 1.)

Because the fine dead fuel moisture model is described in detail in Part 1 (p. 28-35), only an overview is given here. A general flow diagram of the model is shown in figure 29. There are five moisture initialization options to obtain an estimate of the moisture on the previous day. Choice of the option depends on available information. Two examples are direct entry of the moisture value and calculation based on up to 7 days of complete weather. An estimate of the shade is obtained from cloud cover, canopy cover, tree shape, time of year and day, latitude, elevation, and aspect. The moisture content is first calculated for the early afternoon period. Moisture can be calculated for other times of the day based on input of additional weather. A summary of the input requirements is given in Part 1 (fig. 13, p. 34). For the purposes of this model, a day goes from 1200 to 1200 (noon to noon) rather than from midnight to midnight.

MOISTURE offers two run options: burn time calculations and hourly calculations. The first option gives calculated values for the specified burn time. A range of values can be entered for one or two input values in order to produce lists or tables of output values. (SITE does not allow ranges for input variables.) The second option results in hourly values presented in the form of a list or graphs. The hourly values are intermediate values calculated each hour from 1200 to the specified burn time (see Part 1, fig. 14, p. 35). Single values must be assigned to each input for this option.

Burn Time Calculations

Of the 59 possible input values to MOISTURE, 31 are allowed to vary for the table option. You must choose one or two at a time. The choice is narrowed considerably depending on your objective. If you are interested in looking at different fire locations, you will vary site descriptions such as elevation or aspect. If you want to look at the effect of different conditions on the same fire you will vary the weather input.

When doing runs to see the effect of the change of an input value on the results, be careful about making generalizations. In one case there may be little or no effect, but in another a change in that input may be critical. Easterling and others (1986) did a sensitivity analysis of the model and concluded: "combinations of factors have more direct effect on fine fuel moisture than do single factors. Because of the importance of the interaction of minor factors, it is not recommended that any of the model inputs be dropped due to low model sensitivity."

Figure 30 is a MOISTURE run for a range of crown closure values. This example is for fuel model 2 (timber—grass and understory) and a burn time of 1500. Intermediate values from the model are given in addition to 1-hour fuel moisture. As described in a previous section, probability of ignition is always given as an output with MOISTURE because all of the required input are available. Notice the relationship between crown closure and shade. Shade is used in the calculation of fuel level temperature and relative humidity.

Figure 31 is a MOISTURE run for a range of temperature and relative humidity values at burn time. This is a prediction for fuel model 5 (2-foot brush) with no overstory and a burn time of 1500. For this example tables are printed for 1-hour moisture and for probability of ignition. Moisture values are given to a tenth of a percent so that you can see the trends in the predictions. The nearest percentage is good enough for application.

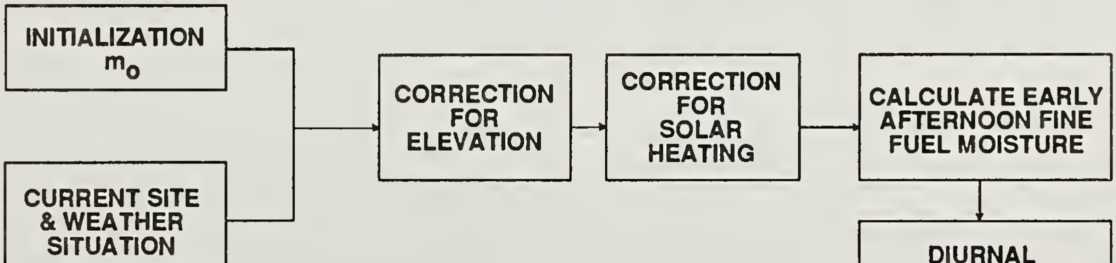


Figure 29—General flow diagram of the fine fuel moisture model that is in SITE and MOISTURE.

```
MOISTURE
 1--RUN OPTION--------------     1=BURN TIME CALCULATIONS
 2--MONTH OF BURN-----------     8.
 3--DAY OF BURN-------------    21.
 4--LATITUDE----------------    47. N
 5--BURN TIME (2400 HOURS)-- 1500.
                               508.=TIME OF SUNRISE
                              1851.=TIME OF SUNSET
 6--FUEL MODEL                   2 = TIMBER (GRASS AND UNDERSTORY)

11--TERRAIN SLOPE, %            50.0
12--ELEVATION OF FIRE
     LOCATION, FT             3000.0
13--ELEVATION OF WEATHER
      OBSERVATIONS, FT------     SAME AS FIRE LOCATION
14--ASPECT------------------     S


15--CROWN CLOSURE, %              .0  10.0  20.0  30.0  40.0  50.0  60.0
16--FOLIAGE-----------------     PRESENT
17--SHADE TOLERANCE---------     TOLERANT
18--DOMINANT TREE TYPE------     1=CONIFEROUS
19--AVERAGE TREE HEIGHT, FT     60.0
20--RATIO OF CROWN LENGTH
     TO TREE HEIGHT--------       .5
21--RATIO OF CROWN LENGTH
     TO CROWN DIAMETER-----      3.0


22--BURN DAY 1400 TEMP, F       80.0
23--BURN DAY 1400 RH, %         30.0
24--BURN DAY 1400 20-FOOT
     WIND SPEED, MI/H            5.0
25--BURN DAY 1400 CLOUD
     COVER, %                     .0
26--BURN DAY 1400 HAZINESS--     2=AVERAGE CLEAR FOREST ATMOSPHERE


    ***BURN TIME WEATHER = 1400 WEATHER***

40--EXPOSURE OF FUELS TO
      THE WIND--------------     2=PARTIALLY SHELTERED
                                  .3=WIND ADJUSTMENT FACTOR

43--MOISTURE INITIALIZATION
      CODE------------------     4=INCOMPLETE WEATHER DATA
                                   NO RAIN THE WEEK BEFORE THE BURN
                                   WEATHER PATTERN HOLDING
```

(V4.0)

CROWN CLOSURE (%)	I	1-HR FUEL MOIS (%)	DRY BULB TEMP (F)	AIR RH (%)	FUEL LEVEL TEMP (F)	FUEL LEVEL RH (%)	MID-FLAME WIND (MI/H)	FUEL LEVEL WIND (MI/H)	SHADE (%)	PROB OF IGN (%)
0.	I	4.2	80.	30.	109.	11.	1.5	1.0	0.	70.
10.	I	4.4	80.	30.	103.	14.	1.5	.9	17.	70.
20.	I	5.0	80.	30.	96.	18.	1.5	.9	33.	60.
30.	I	5.8	80.	30.	90.	22.	1.5	.9	48.	60.
40.	I	6.8	80.	30.	84.	26.	1.5	.9	61.	50.
50.	I	7.7	80.	30.	80.	30.	1.5	.9	72.	40.
60.	I	7.7	80.	30.	80.	30.	1.5	.9	81.	40.

Figure 30—Example MOISTURE run for a range of crown closure values. Note the relationship between crown closure and percent shade.

```
MOISTURE
 1--RUN OPTION-------------    1=BURN TIME CALCULATIONS
 2--MONTH OF BURN----------    6.
 3--DAY OF BURN------------   25.
 4--LATITUDE---------------   40. N
 5--BURN TIME (2400 HOURS)-- 1500.
                              435.=TIME OF SUNRISE
                             1925.=TIME OF SUNSET
 6--FUEL MODEL                 5 = BRUSH (2 FT)

11--TERRAIN SLOPE, %          10.0
12--ELEVATION OF FIRE
     LOCATION, FT            2500.0
13--ELEVATION OF WEATHER
      OBSERVATIONS, FT------    SAME AS FIRE LOCATION
14--ASPECT-----------------    SE


15--CROWN CLOSURE, %             .0


22--BURN DAY 1400 TEMP, F      50.0  60.0  70.0  80.0  90.0 100.0
23--BURN DAY 1400 RH, %        20.0  30.0  40.0  50.0  60.0  70.0
24--BURN DAY 1400 20-FOOT
     WIND SPEED, MI/H         10.0
25--BURN DAY 1400 CLOUD
     COVER, %                   .0
26--BURN DAY 1400 HAZINESS--    1=VERY CLEAR SKY


    ***BURN TIME WEATHER = 1400 WEATHER***

40--EXPOSURE OF FUELS TO
      THE WIND--------------    1=EXPOSED
                                 .4=WIND ADJUSTMENT FACTOR

43--MOISTURE INITIALIZATION
      CODE------------------    4=INCOMPLETE WEATHER DATA
                                  NO RAIN THE WEEK BEFORE THE BURN
                                  WEATHER PATTERN HOLDING
```

Figure 31—Example MOISTURE run for ranges of burn time temperature and relative humidity.

1-HR FUEL MOISTURE, %						(V4.0)
BURN TIME TEMP (F)	BURN TIME RELATIVE HUMIDITY, %					
	20.	30.	40.	50.	60.	70.
50.	4.2	5.7	7.0	8.1	9.0	9.6
60.	4.2	4.6	5.6	6.6	7.5	8.4
70.	4.2	4.5	5.4	6.3	7.1	7.9
80.	4.2	4.4	5.3	6.0	6.8	7.5
90.	4.2	4.4	5.1	5.9	6.5	7.2
100.	4.1	4.4	5.1	5.7	6.3	6.9

PROBABILITY OF IGNITION, %						(V4.0)
BURN TIME TEMP (F)	BURN TIME RELATIVE HUMIDITY, %					
	20.	30.	40.	50.	60.	70.
50.	60.	50.	40.	40.	30.	30.
60.	70.	60.	60.	50.	40.	40.
70.	70.	70.	60.	50.	50.	40.
80.	70.	70.	60.	60.	50.	50.
90.	80.	70.	70.	60.	50.	50.
100.	80.	80.	70.	60.	60.	50.

Figure 31 (Con.)

Hourly Calculations

In order to calculate fuel moisture at burn time, calculations are done for each hour starting at 1200. The hourly calculation option of MOISTURE allows you to examine those values, in the form of either a table or a graph. Because this is essentially one set of calculations, a single value is required for each input. Because a burn day goes from 1200 to 1200, in order to see a 24-hour prediction, you must enter a burn time from the interval 1100 to 1159.

Figure 32 gives a MOISTURE run under the hourly calculation option for a burn time of 1100. One of the output choices is a table listing of the hourly values from 1200 to burn time. Any of the values on that table can be plotted. We show here only the 1-hour moisture plot. The graph is not smooth because of the resolution of the character-type graph. We have sketched in a smooth curve. Sunrise and sunset are denoted on the graph by R and S.

Appendix A includes complete runs of the MOISTURE module showing questions and user response.

RELATIVE HUMIDITY (RH)

The RH module determines relative humidity and dew point from wet bulb and dry bulb temperatures and elevation. This is an alternative to using tables such as those in the S-390 Fire Behavior Field Guide, p. 19-33 (National Wildfire Coordinating Group 1981). But because the RH module uses equations, the results may be slightly different.

Figure 33 shows tables of relative humidity and dew point for ranges of wet bulb and dry bulb temperatures. Wet bulb temperature must be greater than the dry bulb temperature as indicated by the –888. values in the upper right corner of the tables. At the lower left corner, –999. values indicate that the calculated dew point is too low for valid calculations.

```
MOISTURE
 1--RUN OPTION---------------    2=HOURLY CALCULATIONS (GRAPHIC OUTPUT)
 2--MONTH OF BURN------------    2.
 3--DAY OF BURN--------------   10.
 4--LATITUDE-----------------   33. N
 5--BURN TIME (2400 HOURS)-- 1100.
                              639.=TIME OF SUNRISE
                             1720.=TIME OF SUNSET
 6--FUEL MODEL                  7 = SOUTHERN ROUGH

11--TERRAIN SLOPE, %             .0
12--ELEVATION OF FIRE
     LOCATION, FT             300.0
13--ELEVATION OF WEATHER
      OBSERVATIONS, FT------    SAME AS FIRE LOCATION

15--CROWN CLOSURE, %           50.0
16--FOLIAGE-----------------    ABSENT
18--DOMINANT TREE TYPE------    2=DECIDUOUS
19--AVERAGE TREE HEIGHT, FT    50.0
20--RATIO OF CROWN LENGTH
     TO TREE HEIGHT--------      .5
21--RATIO OF CROWN LENGTH
     TO CROWN DIAMETER-----     1.0

22--BURN DAY 1400 TEMP, F      80.0
23--BURN DAY 1400 RH, %        60.0
24--BURN DAY 1400 20-FOOT
     WIND SPEED, MI/H           5.0
25--BURN DAY 1400 CLOUD
     COVER, %                  10.0
26--BURN DAY 1400 HAZINESS--    3=MODERATE FOREST BLUE HAZE

27--SUNSET TEMPERATURE, F      70.0
28--SUNSET RH, %               60.0
29--SUNSET 20-FOOT
     WIND SPEED, MI/H            .0
30--SUNSET CLOUD COVER, %      30.0

31--SUNRISE TEMPERATURE, F     60.0
32--SUNRISE RH, %              60.0
29--SUNRISE 20-FOOT
     WIND SPEED, MI/H            .0
34--SUNRISE CLOUD COVER, %       .0

35--BURN TIME TEMPERATURE, F   60.0
36--BURN TIME RH, %            50.0
37--BURN TIME 20-FOOT
     WIND SPEED, MI/H            .0
38--BURN TIME CLOUD COVER, %     .0
39--BURN TIME HAZINESS------    3=MODERATE FOREST BLUE HAZE
40--EXPOSURE OF FUELS TO
      THE WIND--------------    2=PARTIALLY SHELTERED
                                 .3=WIND ADJUSTMENT FACTOR

43--MOISTURE INITIALIZATION
      CODE------------------    1=1-HR FUEL MOISTURE KNOWN FOR BURN DAY -1
44--BURN DAY -1 1-HR FUEL
      MOISTURE, %-----------    9.0
```

Figure 32—Example MOISTURE run under the hourly output option. A table of hourly values and a plot of 1-hour fuel moisture are given.

(VERSION 4.0)

LOCAL SUN TIME (HR)	1-HR FUEL MOIS (%)	DRY BULB TEMP (F)	AIR RH (%)	FUEL LEVEL TEMP (F)	FUEL LEVEL RH (%)	MID-FLAME WIND (MI/H)	FUEL LEVEL WIND (MI/H)	SHADE (%)	PROB OF IGN (%)
1200	8.9	80.	60.	92.	40.	1.5	.8	14.	40.
1300	8.9	80.	60.	92.	40.	1.5	.8	14.	40.
1400	8.9	80.	60.	92.	40.	1.5	.8	14.	40.
1500	9.0	79.	60.	86.	47.	1.1	.6	22.	30.
1600	9.4	76.	60.	78.	55.	.6	.3	31.	30.
1700	9.9	72.	60.	72.	60.	.2	.1	55.	30.
1800	10.2	69.	60.	69.	60.	.0	.0	100.	30.
1900	10.6	68.	60.	68.	60.	.0	.0	100.	20.
2000	10.9	67.	60.	67.	60.	.0	.0	100.	20.
2100	11.1	66.	60.	66.	60.	.0	.0	100.	20.
2200	11.4	65.	60.	65.	60.	.0	.0	100.	20.
2300	11.6	64.	60.	64.	60.	.0	.0	100.	20.
2400	11.8	63.	60.	63.	60.	.0	.0	100.	20.
100	12.1	62.	60.	62.	60.	.0	.0	100.	20.
200	12.2	61.	60.	61.	60.	.0	.0	100.	20.
300	12.4	61.	60.	61.	60.	.0	.0	100.	20.
400	12.6	60.	60.	60.	60.	.0	.0	100.	20.
500	12.7	60.	60.	60.	60.	.0	.0	100.	20.
600	12.9	60.	60.	60.	60.	.0	.0	100.	20.
700	13.0	60.	60.	60.	60.	.0	.0	39.	20.
800	13.0	60.	59.	64.	51.	.0	.0	11.	20.
900	12.8	60.	57.	73.	37.	.0	.0	7.	20.
1000	12.2	60.	54.	81.	27.	.0	.0	5.	20.
1100	11.3	60.	50.	86.	21.	.0	.0	4.	20.

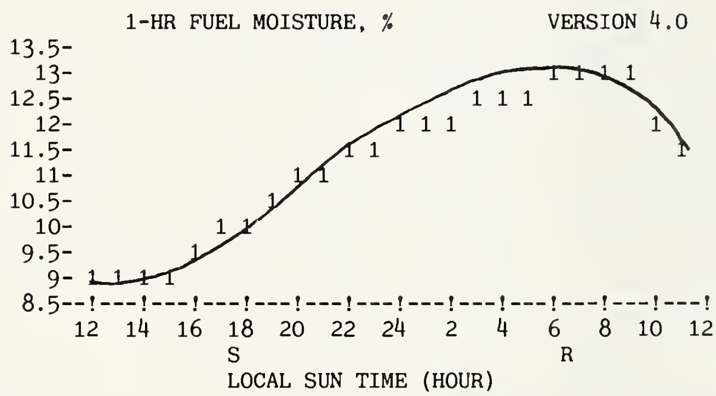


Figure 32 (Con.)

```
RH
 1--DRY BULB TEMPERATURE, F     65.0  70.0  75.0  80.0  85.0  90.0  95.0
 2--WET BULB TEMPERATURE, F     50.0  55.0  60.0  65.0  70.0  75.0  80.0
 3--ELEVATION, FT             2000.0


=================================================================
RELATIVE HUMIDITY, %                                       (V4.0)
=================================================================
    DRY     I       WET BULB TEMPERATURE, DEG F
    BULB    I
    TEMP    I   50.    55.    60.    65.    70.    75.    80.
     (F)    I----------------------------------------------------
            I
    65.     I   33.    53.    76.   100.  -888.  -888.  -888.
            I
    70.     I   21.    38.    57.    77.   100.  -888.  -888.
            I
    75.     I   12.    26.    42.    59.    79.   100.  -888.
            I
    80.     I    5.    17.    30.    45.    62.    80.   100.
            I
    85.     I -999.    10.    22.    34.    48.    63.    81.
            I
    90.     I -999.     5.    15.    25.    37.    50.    65.
            I
    95.     I -999.     1.    10.    19.    29.    40.    53.

    -888 = WET BULB TEMPERATURE GREATER THAN DRY BULB.

    -999 = DEW POINT IS LESS THAN -40 DEGREES.


=================================================================
DEW POINT, F                                               (V4.0)
=================================================================
    DRY     I       WET BULB TEMPERATURE, DEG F
    BULB    I
    TEMP    I   50.    55.    60.    65.    70.    75.    80.
     (F)    I----------------------------------------------------
            I
    65.     I   36.    48.    57.    65.  -888.  -888.  -888.
            I
    70.     I   29.    43.    54.    63.    70.  -888.  -888.
            I
    75.     I   19.    38.    50.    60.    68.    75.  -888.
            I
    80.     I    4.    32.    46.    57.    66.    73.    80.
            I
    85.     I -999.    23.    42.    54.    63.    71.    78.
            I
    90.     I -999.    11.    36.    50.    60.    69.    77.
            I
    95.     I -999.   -14.    29.    46.    58.    67.    75.

    -888 = WET BULB TEMPERATURE GREATER THAN DRY BULB.

    -999 = DEW POINT IS LESS THAN -40 DEGREES.
```

Figure 33—Example RH run.

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APPENDIX A—ANNOTATED RUNS OF THE FIRE1 AND FIRE2 PROGRAMS OF BEHAVE.

Fire behavior prediction models that have been added to BEHAVE are illustrated in the body of the paper with sample input and output from the programs. This appendix provides complete user sessions for the FIRE1 and FIRE2 programs, with all of the interaction between the user and the computer. Basic operation is emphasized in the sample run in appendix A of Part 1 (Andrews 1986); that information is still valid. This run is used to illustrate the changes and additions to the programs.

Lines that begin with a > (the prompt symbol) were typed by the user. All others were printed by the computer. The prompt symbol may be different on another computer. (The Forest Service Data General system does not give a prompt.)

Gaining access to the BEHAVE programs and printing log files are functions of the computer being used and therefore are not described in this manual.

Contents

```
WELCOME TO THE BEHAVE SYSTEM
  BURN SUBSYSTEM
    FIRE1 PROGRAM: VERSION 4.0 -- MAY 1989

DEVELOPED BY:  THE FIRE BEHAVIOR RESEARCH WORK UNIT
               INTERMOUNTAIN FIRE SCIENCES LABORATORY
               MISSOULA, MONTANA

YOU ARE RESPONSIBLE FOR SUPPLYING VALID INPUT AND FOR
  CORRECTLY INTERPRETING THE FIRE BEHAVIOR PREDICTIONS.
```

This is important.

```
ASSUMPTIONS, LIMITATIONS, AND APPLICATION OF MATHEMATICAL
  MODELS USED IN THIS PROGRAM ARE IN:
  Andrews, Patricia L. "BEHAVE: Fire behavior prediction and
    fuel modeling system--BURN subsystem, Part 1", INT-GTR-194, 1986
  Andrews, Patricia L., and Chase, Carolyn H. "BEHAVE: Fire
    behavior prediction and fuel modeling system--BURN
    subsystem, Part 2", INT-GTR-260, 1989

(PRESS CARRIAGE RETURN TO CONTINUE)
>

PAUSE OPTION AND ENGLISH UNITS SET.
  SLOPE MEASUREMENT IN PERCENT.
WHEN YOU ARE READY TO CONTINUE AFTER THE PROMPT
SYMBOL IS PRINTED WITHOUT A QUESTION,
PRESS THE CARRIAGE RETURN KEY.

TYPE 'CUSTOM' IF YOU ARE GOING TO USE CUSTOM FUEL MODELS.

FIRE1 KEYWORD?
ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
      MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>status
```

The program recognizes only upper case input. Use your shift lock key.

```
****ALL UPPER CASE PLEASE****

FIRE1 KEYWORD?
ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
      MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>STAT
```

These are new keywords.

The program checks only the first four letters of keywords.

```
**** FIRE1 STATUS REQUEST ****
    PROMPT MODE   :  WORDY
    DISPLAY MODE  :  PAUSE
    LOG FILE NAME :  UNDECLARED
    LOG FUNCTION  :  OFF
    FUEL FILE NAME:  UNDECLARED
    DISPLAY UNITS :  ENGLISH
    SLOPE UNITS   :  PERCENT
```

Default values for mode keywords.

```
FIRE1 KEYWORD?
ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
      MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>COMMENT

NO LOG FILE CURRENTLY ACTIVE.  REMEMBER THAT THIS
  COMMENT APPEARS ONLY ON YOUR TERMINAL--NOT IN ANY LOG FILE.

ENTER TEXT FOR DOCUMENTATION.
  USE A CARRIAGE RETURN AT THE END OF EACH LINE.
  TO TERMINATE, ENTER (ON A NEW LINE) **
  FOLLOWED BY A CARRIAGE RETURN.
```

On non-printing terminals, COMMENT is useful only if the LOG option is activated. However, the program gives you the choice of continuing if you are using a printing terminal.

```
********************************************************************************
COMMENT:
>**
********************************************************************************
```

Let's terminate the comment and specify a log file.

```
FIRE1 KEYWORD?
ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
      MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>LOG

WHAT FILE NAME DO YOU WANT TO USE? (12 CHARACTERS MAX)
  FIRST CHARACTER MUST BE ALPHABETIC.  FOLLOW THE NAMING
  CONVENTION FOR YOUR COMPUTER.
>LOGFIL

LOG IS ON.
THE NAME OF YOUR LOGFILE IS: LOGFIL

FIRE1 KEYWORD?
ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
      MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>STATUS
```

This is a new file. Specifying an existing file will be covered later. Once a file has been attached to the run, it remains the same until the run is terminated.

```
**** FIRE1 STATUS REQUEST ****
    PROMPT MODE    :  WORDY
    DISPLAY MODE   :  PAUSE
    LOG FILE NAME  :  LOGFIL
    LOG FUNCTION   :  ON
    FUEL FILE NAME:   UNDECLARED
    DISPLAY UNITS  :  ENGLISH
    SLOPE UNITS    :  PERCENT
```

A log file has been declared.

The log function can be turned on and off at any time during the run.

```
FIRE1 KEYWORD?
ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
      MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>COMMENT

ENTER TEXT FOR DOCUMENTATION.
  USE A CARRIAGE RETURN AT THE END OF EACH LINE.
  TO TERMINATE, ENTER (ON A NEW LINE) **
  FOLLOWED BY A CARRIAGE RETURN.
```

Characters typed after the 80th and before a return will be lost (even if the cursor automatically moves to the next line).

```
****************************************************************************
COMMENT:
>AN FBA MIGHT USE THE COMMENT KEYWORD TO LABEL A DIRECT RUN WITH
>      1.  FIRE NAME
>      2.  PROJECTION TIME AND DATE
>**
****************************************************************************
```

One suggestion for the use of COMMENT. Use it however you wish.

```
FIRE1 KEYWORD?
ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
      MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>SLOPE

SLOPE KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>INPUT

(1) MAP SCALE OPTION ? 1-2 OR QUIT
      1=REPRESENTATIVE FRACTION
      2=INCHES PER MILE
>2

(1) MAP SCALE, IN/MI ? .1-20
>2.64
```

Input to the hundredths place is OK only for map scale and precipitation amount.

```
 *(2) CONTOUR INTERVAL, FT ? 10-500
>40

 *(3) MAP DISTANCE, IN ? .1-10
>1

 *(4) NUMBER OF CONTOUR INTERVALS ? 1-100
>5,9,2

 THE FOLLOWING VALUES WILL BE USED
    5.0    7.0    9.0
 OK ? Y-N
>Y

 SLOPE KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST


 SLOPE
  1--MAP SCALE, IN/MI--------     2.64
                                  1: 24000.
  2--CONTOUR INTERVAL, FT ---    40.0
  3--MAP DISTANCE, IN -------     1.0
  4--NUMBER CONTOUR INTERVALS     5.0    7.0    9.0

 SLOPE KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN


          (V4.0)
  NUMBER      I
    OF        I   TERRAIN       ELEVATION    HORIZONTAL
 CONTOUR      I    SLOPE         CHANGE       DISTANCE
 INTERVLS     I   (%   )          (FT)          (FT)
              I
    5.0       I     10.           200.          2000.
              I
    7.0       I     14.           280.          2000.
              I
    9.0       I     18.           360.          2000.
```

* before an input prompt indicates that a range of input is OK.

The version number of the program is printed with all RUN output.

```
 SLOPE KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>DEGREES
```

Let's look at slope in degrees.

```
 CURRENT UNITS SYSTEM: ENGLISH.   SLOPE IS IN DEGREES

 SLOPE KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN


          (V4.0)
 NUMBER     I
   OF       I    TERRAIN        ELEVATION    HORIZONTAL
 CONTOUR    I     SLOPE          CHANGE       DISTANCE
 INTERVLS   I     (DEG)           (FT)          (FT)
            I
    5.0     I       6.            200.         2000.
            I
    7.0     I       8.            280.         2000.
            I
    9.0     I      10.            360.         2000.
```

Compare these values with those marked in the previous run.

```
 SLOPE KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>PERCENT
```

Back to our usual units.

```
 CURRENT UNITS SYSTEM: ENGLISH.   SLOPE IS IN PERCENT

 SLOPE KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>QUIT

 FINISH SLOPE --BACK TO FIRE1
```

```
 FIRE1 KEYWORD?
 ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
       MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS,QUIT
>DIRECT


 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
       SIZE,SCORCH
>INPUT

 (1) FUEL MODEL ? 0-99 OR QUIT
       (ENTER 0 FOR TWO FUEL MODEL CONCEPT INPUT.)
>5
```

Link to SCORCH and SPOT is not allowed with the two-fuel-model concept.

```
 *(2) 1-HR FUEL MOISTURE, % ? 1-60
>5

 *(3) 10-HR FUEL MOISTURE, % ? 1-60
>6

 *(6) LIVE WOODY MOISTURE, % ? 30-300
>90

 *(7) MIDFLAME WINDSPEED, MI/H ? 0-99
>1,5,1

 THE FOLLOWING VALUES WILL BE USED
    1.0    2.0    3.0    4.0    5.0
 OK ? Y-N
>Y

 *(8) TERRAIN SLOPE, % ? 0-100
>40,100,10

 THE FOLLOWING VALUES WILL BE USED
   40.0   50.0   60.0   70.0   80.0   90.0  100.0
 OK ? Y-N
>Y

 *(9) DIRECTION OF WIND VECTOR,
       DEGREES CLOCKWISE FROM UPHILL ? 0-360
>40
```

You can INPUT in English units ...

```
 (10) DO YOU WANT FIRE BEHAVIOR PREDICTIONS FOR
      THE DIRECTION OF MAXIMUM SPREAD ? Y-N
>Y
```

```
 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>METRIC
```

then switch to metric to run.

```
 CURRENT UNITS SYSTEM:  METRIC.   SLOPE IS IN PERCENT

 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST
```

Note that METRIC and ENGLISH do not affect slope units.

```
 DIRECT
  1--FUEL MODEL -------------      5 -- BRUSH, 2 FT (60 CM)
  2--1-HR FUEL MOISTURE, % --    5.0
  3--10-HR FUEL MOISTURE, % -    6.0
  6--LIVE WOODY MOISTURE, % -   90.0
  7--MIDFLAME WINDSPEED, KM/H    1.6    3.2    4.8    6.4    8.0
  8--TERRAIN SLOPE, % -------   40.0   50.0   60.0   70.0   80.0   90.0 100.0
  9--DIRECTION OF WIND VECTOR   40.0
       DEGREES CLOCKWISE
        FROM UPHILL
 10--DIRECTION OF SPREAD ----   DIRECTION OF MAXIMUM SPREAD
       CALCULATIONS               TO  BE CALCULATED
       DEGREES CLOCKWISE
        FROM UPHILL
```

Non-integer values are due to conversion to metric units.

Note for later reference.

```
 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN

 TABLE VARIABLE ? 0-7

  0=NO MORE TABLES        4=FLAME LENGTH
  1=RATE OF SPREAD        5=REACTION INTENSITY
  2=HEAT PER UNIT AREA    6=EFFECTIVE WINDSPEED
  3=FIRELINE INTENSITY    7=DIRECTION OF MAX SPREAD
>4
```

```
==================================================================
FLAME LENGTH, M                                            (V4.0)
==================================================================
MIDFLAME I       TERRAIN SLOPE, %
  WIND   I
         I    40.0   50.0   60.0   70.0   80.0   90.0  100.0
 (KM/H)  I---------------------------------------------------------
         I
 1.6     I    1.3    1.5    1.7    1.9    2.1    2.3    2.5
         I
 3.2     I    1.5    1.7    1.8    2.0    2.2    2.4    2.6
         I
 4.8     I    1.7    1.9    2.0    2.2    2.4    2.5    2.7
         I
 6.4     I    2.0    2.1    2.2    2.4    2.5    2.7    2.9
         I
 8.0     I    2.2    2.3    2.4    2.5    2.7    2.8    3.0
```

The flame lengths are in meters.

```
TABLE VARIABLE ? 0-7

 0=NO MORE TABLES       4=FLAME LENGTH
 1=RATE OF SPREAD       5=REACTION INTENSITY
 2=HEAT PER UNIT AREA   6=EFFECTIVE WINDSPEED
 3=FIRELINE INTENSITY   7=DIRECTION OF MAX SPREAD
>0


IF YOU WANT TO CONTINUE WITH THE AREA AND PERIMETER CALCULATIONS,
  TYPE 'SIZE'
IF YOU WANT TO CONTINUE WITH SCORCH HEIGHT CALCULATIONS,
  TYPE 'SCORCH'
IF YOU WANT TO CONTINUE WITH SPOTTING DISTANCE FROM
  A WIND-DRIVEN SURFACE FIRE, TYPE 'SPOT'

DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
      SIZE,SCORCH,SPOT
>ENGLISH
```

Back to English units.

```
CURRENT UNITS SYSTEM:  ENGLISH.  SLOPE IS IN PERCENT.

DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
      SIZE,SCORCH,SPOT
>RUN
```

```
TABLE VARIABLE ? 0-7

 0=NO MORE TABLES       4=FLAME LENGTH
 1=RATE OF SPREAD       5=REACTION INTENSITY
 2=HEAT PER UNIT AREA   6=EFFECTIVE WINDSPEED
 3=FIRELINE INTENSITY   7=DIRECTION OF MAX SPREAD
>7


=================================================================
DIRECTION OF MAXIMUM SPREAD, DEG                           (V4.0)
=================================================================
MIDFLAME I        TERRAIN SLOPE, %
  WIND   I
         I   40.0   50.0   60.0   70.0   80.0   90.0  100.0
 (MI/H)  I-------------------------------------------------------
         I
 1.0     I   12.     8.     6.     5.     4.     3.     2.
         I
 2.0     I   21.    17.    13.    10.     8.     7.     6.
         I
 3.0     I   27.    22.    19.    16.    13.    11.     9.
         I
 4.0     I   30.    26.    23.    20.    17.    15.    13.
         I
 5.0     I   32.    29.    26.    23.    20.    18.    16.
```

This will be referred to later.

```
TABLE VARIABLE ? 0-7

 0=NO MORE TABLES       4=FLAME LENGTH
 1=RATE OF SPREAD       5=REACTION INTENSITY
 2=HEAT PER UNIT AREA   6=EFFECTIVE WINDSPEED
 3=FIRELINE INTENSITY   7=DIRECTION OF MAX SPREAD
>0


IF YOU WANT TO CONTINUE WITH THE AREA AND PERIMETER CALCULATIONS,
  TYPE 'SIZE'
IF YOU WANT TO CONTINUE WITH SCORCH HEIGHT CALCULATIONS,
  TYPE 'SCORCH'
IF YOU WANT TO CONTINUE WITH SPOTTING DISTANCE FROM
  A WIND-DRIVEN SURFACE FIRE, TYPE 'SPOT'
```

Link to SPOT is allowed only for a head fire.

```
DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
      SIZE,SCORCH,SPOT
>SPOT
```

```
SPOT-LINKED-TO-DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>INPUT
```

Keyword requests and lists are labeled to help you keep track of where you are.

```
 *(4) RIDGE/VALLEY ELEVATIONAL DIFFERENCE, FT ? 0-4000
>1000

 *(5) RIDGE/VALLEY HORIZONTAL DISTANCE, MI ? 0-4
>1.

 (6) SPOTTING SOURCE LOCATION ? 0-3
      0=MIDSLOPE, WINDWARD SIDE
      1=VALLEY BOTTOM
      2=MIDSLOPE,LEEWARD SIDE
      3=RIDGETOP
>1

 SPOT-LINKED-TO-DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST
```

only option available for SPOT linked to DIRECT

To emphasize that wind-driven surface fire calculations apply only when there is no significant timber cover

```
 SPOT-LINKED-TO-DIRECT
  1--FIREBRAND SOURCE--------    3--WIND-DRIVEN SURFACE FIRE
  2--MEAN COVER HEIGHT, FT --      .0
  3--20-FOOT WINDSPEED, MI/H      2.5    5.0    7.5   10.0   12.5
       FROM MIDFLAME WIND =       1.0    2.0    3.0    4.0    5.0
       & EXPOSED FUEL WAF =        .4
  4--RIDGE/VALLEY ELEVATION
            DIFFERENCE, FT -- 1000.0
  5--RIDGE/VALLEY HORIZONTAL
            DISTANCE, MI ----     1.0
  6--SPOTTING SOURCE LOCATION    1.-- VALLEY BOTTOM
 12--FLAME LENGTH, FT -------    OUTPUT FROM DIRECT. RANGE=   4.2 TO    9.9
```

saved from DIRECT

```
 SPOT-LINKED-TO-DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN
```

20-ft wind is calculated from midflame wind input in DIRECT and the wind adjustment factor for the fuel model from DIRECT (does not use effective windspeed)

SPOT input lines 1,2,3,12 cannot be changed in linked runs.

```
=================================================================
MAXIMUM SPOTTING DISTANCE, MI                              (V4.0)
=================================================================
  MIDFLAME  I        TERRAIN SLOPE, %
    WIND    I
            I   40.0   50.0   60.0   70.0   80.0   90.0  100.0
   (MI/H)   I-----------------------------------------------------
            I
    1.0     I     .1   -1.0   -1.0   -1.0   -1.0   -1.0   -1.0
            I
    2.0     I     .1     .1     .1     .1   -1.0   -1.0   -1.0
            I
    3.0     I     .1     .2     .2     .2     .2     .2   -1.0
            I
    4.0     I     .2     .2     .2     .2     .2     .2     .3
            I
    5.0     I     .2     .3     .3     .3     .3     .3     .3

    -1.=THIS IS NOT A WIND-DRIVEN HEAD FIRE.
         THE DIRECTION OF MAXIMUM SPREAD IS MORE THEN 30
         DEGREES FROM THE DIRECTION OF THE WIND VECTOR.
```

Note! See line 7 of DIRECT listing and direction of max spread output.

```
 SPOT-LINKED-TO-DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>QUIT

 FINISH SPOT LINKED TO DIRECT-BACK TO DIRECT

 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>QUIT

 FINISH DIRECT --BACK TO FIRE1
```

QUIT all the way back to FIRE1

```
 FIRE1 KEYWORD?
 ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
       MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS,QUIT
>MORTALITY
```

and run MORTALITY as an independent module.

```
 MORTALITY KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>INPUT

 *(1) SCORCH HEIGHT, FT ? 1-200 OR QUIT
>30

 *(2) TREE HEIGHT, FT ? 20-200
>20,110,45

 THE FOLLOWING VALUES WILL BE USED
   20.0   65.0   110.0
 OK ? Y-N
>Y

 *(3) CROWN RATIO ? .1-1
>.8

 (4) BARK THICKNESS OPTION ? 1-2
       1=DETERMINE BY SPECIES AND DBH
       2=DIRECT ENTRY
>1

 (4) TREE SPECIES ? 1-5
       1=WESTERN LARCH, DOUGLAS-FIR
       2=WESTERN HEMLOCK
       3=ENGELMANN SPRUCE, WESTERN RED CEDAR
       4=LODGEPOLE PINE, SUBALPINE FIR
       5=NONE OF THESE
>3

 *(4) TREE DBH, IN ? 5-50
>5,25,10

 THE FOLLOWING VALUES WILL BE USED
    5.0   15.0   25.0
 OK ? Y-N
>Y

 MORTALITY KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST
```

Bark thickness is the MORTALITY input. These are the options for getting the values in.

These choices result in a prompt for bark thickness –

or choose a ~~species~~ with bark thickness similar to the one you are interested in

```
MORTALITY
 1--SCORCH HEIGHT, FT ------    30.0
 2--TREE HEIGHT, FT --------    20.0   65.0 110.0
 3--CROWN RATIO ------------      .8
 4--BARK THICKNESS, IN -----      .2     .4    .6
      FROM: SPECIES               3=ENGELMANN SPRUCE, WESTERN RED CEDAR
            DBH, IN               5.0   15.0   25.0
```

These values are calculated from species and DBH.

```
MORTALITY KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>RUN

TABLE VARIABLE ? 0-2

  0=NO MORE TABLES
  1=MORTALITY LEVEL
  2=CROWN VOLUME SCORCH
>1


==================================================================
MORTALITY LEVEL, %                                          (V4.0)
==================================================================
  TREE   I       TREE DBH, IN
 HEIGHT  I
         I    5.0   15.0   25.0
  (FT)   I---------------------------------------------------------
         I
  20.0   I   100.    99.    97.
         I
  65.0   I    90.    78.    62.
         I
 110.0   I    68.    46.    28.
```

Calculations are made for all input combinations specified. The user must determine which combinations are unrealistic.

```
TABLE VARIABLE ? 0-2

  0=NO MORE TABLES
  1=MORTALITY LEVEL
  2=CROWN VOLUME SCORCH
>0

MORTALITY KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>QUIT

FINISH MORTALITY--BACK TO FIRE1
```

```
 FIRE1 KEYWORD?
 ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
       MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS,QUIT
>SCORCH

 SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>INPUT

 *(1) AMBIENT AIR TEMPERATURE, F ? 33-120 OR QUIT
>85

 *(2) FLAME LENGTH, FT ? .1-100
>8

 *(3) MIDFLAME WINDSPEED, MI/H ? 0-99
>5

 SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST


 SCORCH
  1--AMBIENT AIR TEMP, F ----   85.0
  2--FLAME LENGTH, FT -------    8.0
  3--MIDFLAME WINDSPEED, MI/H    5.0

 SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN


     (VERSION 4.0)

     CROWN SCORCH HEIGHT, FT              67.
```

SCORCH independent

```
 SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
       MORTALITY
>MORTALITY
```

Mortality linked to scorch

```
 MORTALITY-LINKED-TO-SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>INPUT

 *(2) TREE HEIGHT, FT ? 20-200
>20,110,45

 THE FOLLOWING VALUES WILL BE USED
   20.0   65.0  110.0
 OK ? Y-N
>Y

 *(3) CROWN RATIO ? .1-1
>.8

 (4) BARK THICKNESS OPTION ? 1-2
       1=DETERMINE BY SPECIES AND DBH
       2=DIRECT ENTRY
>2

 (4) BARK THICKNESS, IN ? .1-5
>.2,.6,.2
```

Enter bark thickness directly this time.

```
 THE FOLLOWING VALUES WILL BE USED
     .2     .4     .6
 OK ? Y-N
>Y

 MORTALITY-LINKED-TO-SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST


 MORTALITY-LINKED-TO-SCORCH
  1--SCORCH HEIGHT, FT ------    OUTPUT FROM SCORCH =  67.
  2--TREE HEIGHT, FT --------   20.0  65.0 110.0
  3--CROWN RATIO ------------     .8
  4--BARK THICKNESS, IN -----     .2     .4     .6
       (DIRECT ENTRY)
```

This value has been carried over from SCORCH.

```
 MORTALITY-LINKED-TO-SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN

 TABLE VARIABLE ? 0-2

   0=NO MORE TABLES
   1=MORTALITY LEVEL
   2=CROWN VOLUME SCORCH
>1


 ==================================================================
 MORTALITY LEVEL, %                                          (V4.0)
 ==================================================================
   TREE   I       TREE DBH, IN
  HEIGHT  I
          I    5.0   15.0   25.0
   (FT)   I--------------------------------------------------------
          I
   20.0   I    99.    99.    98.
          I
   65.0   I    99.    99.    98.
          I
  110.0   I    97.    94.    88.

 TABLE VARIABLE ? 0-2

   0=NO MORE TABLES
   1=MORTALITY LEVEL
   2=CROWN VOLUME SCORCH
>0

 MORTALITY-LINKED-TO-SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>QUIT

 FINISH MORTALITY LINKED TO SCORCH--BACK TO SCORCH

 SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
       MORTALITY
>QUIT

 FINISH SCORCH -BACK TO FIRE1
```

```
 FIRE1 KEYWORD?
 ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
       MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS,QUIT
>DIRECT

 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>INPUT

 (1) FUEL MODEL ? 0-99 OR QUIT
       (ENTER 0 FOR TWO FUEL MODEL CONCEPT INPUT.)
>10

 *(2) 1-HR FUEL MOISTURE, % ? 1-60
>5,11,2

 THE FOLLOWING VALUES WILL BE USED
    5.0     7.0     9.0    11.0
 OK ? Y-N
>Y

 *(3) 10-HR FUEL MOISTURE, % ? 1-60
>7

 *(4) 100-HR FUEL MOISTURE, % ? 1-60
>8

 *(6) LIVE WOODY MOISTURE, % ? 30-300
>150

 *(7) MIDFLAME WINDSPEED, MI/H ? 0-99
>4,14,2

 THE FOLLOWING VALUES WILL BE USED
    4.0     6.0     8.0    10.0    12.0    14.0
 OK ? Y-N
>Y

 *(8) TERRAIN SLOPE, % ? 0-100
>15

 *(9) DIRECTION OF WIND VECTOR,
       DEGREES CLOCKWISE FROM UPHILL ? 0-360
>0
```

DIRECT-SCORCH-MORTALITY linked run

```
 (10) DO YOU WANT FIRE BEHAVIOR PREDICTIONS FOR
      THE DIRECTION OF MAXIMUM SPREAD ? Y-N
>Y

 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST


 DIRECT
  1--FUEL MODEL -------------    10 -- TIMBER (LITTER AND UNDERSTORY)
  2--1-HR FUEL MOISTURE, % --    5.0   7.0   9.0  11.0
  3--10-HR FUEL MOISTURE, % -    7.0
  4--100-HR FUEL MOISTURE, %     8.0
  6--LIVE WOODY MOISTURE, % -  150.0
  7--MIDFLAME WINDSPEED, MI/H    4.0   6.0   8.0  10.0  12.0  14.0
  8--TERRAIN SLOPE, % -------   15.0
  9--DIRECTION OF WIND VECTOR     .0
      DEGREES CLOCKWISE
       FROM UPHILL
 10--DIRECTION OF SPREAD ----     .0  (DIRECTION OF MAX SPREAD)
     CALCULATIONS
      DEGREES CLOCKWISE
       FROM UPHILL

 DIRECT KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN

 TABLE VARIABLE ? 0-6

  0=NO MORE TABLES      4=FLAME LENGTH
  1=RATE OF SPREAD      5=REACTION INTENSITY
  2=HEAT PER UNIT AREA  6=EFFECTIVE WINDSPEED
  3=FIRELINE INTENSITY
>4
```

```
================================================================
FLAME LENGTH, FT                                          (V4.0)
================================================================
  1-HR   I       MIDFLAME WIND, MI/H
  MOIS   I
         I     4.0    6.0    8.0   10.0   12.0   14.0
  (%)    I-------------------------------------------------------
         I
 5.0     I    4.1    5.2    6.1    7.0    7.9    8.7
         I
 7.0     I    3.8    4.8    5.7    6.6    7.4    8.2
         I
 9.0     I    3.7    4.6    5.5    6.3    7.1    7.8
         I
11.0     I    3.6    4.5    5.3    6.1    6.9    7.6


TABLE VARIABLE ? 0-6

 0=NO MORE TABLES      4=FLAME LENGTH
 1=RATE OF SPREAD      5=REACTION INTENSITY
 2=HEAT PER UNIT AREA  6=EFFECTIVE WINDSPEED
 3=FIRELINE INTENSITY
>0

IF YOU WANT TO CONTINUE WITH THE AREA AND PERIMETER CALCULATIONS,
  TYPE 'SIZE'
IF YOU WANT TO CONTINUE WITH SCORCH HEIGHT CALCULATIONS,
  TYPE 'SCORCH'
IF YOU WANT TO CONTINUE WITH SPOTTING DISTANCE FROM
  A WIND-DRIVEN SURFACE FIRE, TYPE 'SPOT'

DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
      SIZE,SCORCH,SPOT
>SCORCH

SCORCH-LINKED-TO-DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>INPUT

*(1) AMBIENT AIR TEMPERATURE, F ? 33-120 OR QUIT
>75
```

The only SCORCH input in a linked run.

```
SCORCH-LINKED-TO-DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>LIST
```

these values are carried over from DIRECT.

```
SCORCH-LINKED-TO-DIRECT
 1--AMBIENT AIR TEMP, F ----    75.0
 2--FLAME LENGTH, FT -------    OUTPUT FROM DIRECT.  RANGE =    3.6 TO    8.7
 3--MIDFLAME WINDSPEED, MI/H -  SAVED FROM DIRECT.   RANGE =    4.0 TO   14.0

SCORCH-LINKED-TO-DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>RUN


========================================================================
CROWN SCORCH HEIGHT, FT                                           (V4.0)
========================================================================
    1-HR     I       MIDFLAME WIND, MI/H
    MOIS     I
             I     4.0     6.0     8.0    10.0    12.0    14.0
    (%)      I---------------------------------------------------------
             I
    5.0      I    19.     23.     26.     28.     29.     31.
             I
    7.0      I    17.     20.     22.     24.     25.     26.
             I
    9.0      I    16.     18.     20.     22.     23.     24.
             I
   11.0      I    15.     17.     19.     20.     21.     22.


SCORCH-LINKED-TO-DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
      MORTALITY
>MORTALITY

MORTALITY-LINKED-TO-DIRECT-AND-SCORCH KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>INPUT
```

```
 *(2) TREE HEIGHT, FT ? 20-200
>50

 *(3) CROWN RATIO ? .1-1
>.6

 (4) BARK THICKNESS OPTION ? 1-2
       1=DETERMINE BY SPECIES AND DBH
       2=DIRECT ENTRY
>2

 *(4) BARK THICKNESS, IN ? .1-5
>.1

 MORTALITY-LINKED-TO-DIRECT-AND-SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>LIST


 MORTALITY-LINKED-TO-DIRECT-AND-SCORCH
  1--SCORCH HEIGHT, FT ------    OUTPUT FROM SCORCH. RANGE =   15. TO   31.
  2--TREE HEIGHT, FT --------   50.0
  3--CROWN RATIO ------------     .6
  4--BARK THICKNESS, IN -----     .1
       (DIRECT ENTRY)

 MORTALITY-LINKED-TO-DIRECT-AND-SCORCH KEYWORD?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS
>RUN

 TABLE VARIABLE ? 0-2

   0=NO MORE TABLES
   1=MORTALITY LEVEL
   2=CROWN VOLUME SCORCH
>1
```

```
==================================================================
MORTALITY LEVEL, %                                          (V4.0)
==================================================================
  1-HR   I       MIDFLAME WIND, MI/H
  MOIS   I
         I   4.0     6.0     8.0    10.0    12.0    14.0
  (%)    I---------------------------------------------------------
         I
   5.0   I   73.     77.     84.     89.     92.     94.
         I
   7.0   I   73.     73.     75.     79.     82.     85.
         I
   9.0   I   73.     73.     73.     74.     76.     78.
         I
  11.0   I   73.     73.     73.     73.     74.     75.


TABLE VARIABLE ? 0-2

  0=NO MORE TABLES
  1=MORTALITY LEVEL
  2=CROWN VOLUME SCORCH
>0

MORTALITY-LINKED-TO-DIRECT-AND-SCORCH KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
>QUIT

FINISH MORTALITY LINKED TO SCORCH AND DIRECT--BACK TO SCORCH

SCORCH-LINKED-TO-DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
      MORTALITY
>QUIT

FINISH SCORCH - BACK TO DIRECT


DIRECT KEYWORD?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS
      SIZE,SCORCH,SPOT
>QUIT

FINISH DIRECT -- BACK TO FIRE1
```

```
 FIRE1 KEYWORD?
 ENTER DIRECT,SITE,SIZE,CONTAIN,SCORCH,SPOT,
       MORTALITY,MAP,SLOPE,DISPATCH,CUSTOM,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS,QUIT
>QUIT

 DO YOU  R E A L L Y  WANT TO TERMINATE THIS RUN? Y-N
>Y

 PART OF THIS RUN MAY HAVE BEEN LOGGED.
 THE FILE NAME IS: LOGFIL
 PRINT THE FILE NOW AND DELETE IT.


 FIRE1 RUN TERMINATED.
 ******************************
```

A reminder of your log file name and encouragement to delete it when you no longer need it. You are responsible for your own file maintenance.

```
WELCOME TO THE BEHAVE SYSTEM
  BURN SUBSYSTEM
    FIRE2 PROGRAM: VERSION 4.0 -- MAY 1989

DEVELOPED BY:  THE FIRE BEHAVIOR RESEARCH WORK UNIT
               INTERMOUNTAIN FIRE SCIENCES LABORATORY
               MISSOULA, MONTANA

YOU ARE RESPONSIBLE FOR SUPPLYING VALID INPUT AND FOR
  CORRECTLY INTERPRETING THE FIRE BEHAVIOR PREDICTIONS.

ASSUMPTIONS, LIMITATIONS, AND APPLICATION OF MATHEMATICAL
  MODELS USED IN THIS PROGRAM ARE IN:
  Andrews, Patricia L. "BEHAVE: Fire behavior prediction and
    fuel modeling system--BURN subsystem, Part 1", INT-GTR-194, 1986.
  Andrews, Patricia L., and Chase, Carolyn H. "BEHAVE: Fire
    behavior prediction and fuel modeling system--BURN
    subsystem, Part 2", INT-GTR-260, 1989.

(PRESS RETURN TO CONTINUE)
>

PAUSE OPTION AND ENGLISH UNITS SET.
  SLOPE MEASUREMENT IS IN PERCENT.
WHEN YOU ARE READY TO CONTINUE AFTER THE PROMPT SYMBOL IS
PRINTED WITHOUT A QUESTION, PRESS THE CARRIAGE RETURN KEY.

TYPE 'CUSTOM' IF YOU ARE GOING TO USE CUSTOM FUEL MODELS.

FIRE2 KEYWORD ?
ENTER IGNITE,MOISTURE,RH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
>LOG

WHAT FILE NAME DO YOU WANT TO USE? (12 CHARACTERS MAX)
  FIRST CHARACTER MUST BE ALPHABETIC. FOLLOW THE NAMING
  CONVENTION FOR YOUR COMPUTER.
>LOGFIL
```

We used this file for the FIRE1 run and did not delete. You must make a choice.

```
LOG FILE "LOGFIL" EXISTS.  DO YOU WANT TO
    1=APPEND TO FILE "LOGFIL"
    2=CHANGE TO ANOTHER LOG FILE
    3=DELETE "LOGFIL" AND START A NEW FILE WITH THE SAME NAME
>1

LOG IS ON.
THE NAME OF YOUR LOGFILE IS:  LOGFIL
```

```
 FIRE2 KEYWORD ?
 ENTER IGNITE,MOISTURE,RH,CUSTOM,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY,HELP,STATUS,QUIT
>MOISTURE

 MOISTURE KEYWORD ?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY HELP,STATUS
>INPUT
```

Graphic option

```
 REMINDER:  'BURN DAY' STARTS AT NOON AND CONTINUES FOR 24
            HOURS.  ALL INPUTS ARE IN REFERENCE TO 'BURN DAY.'

 (1) RUN OPTION ? 1-2 OR QUIT
     1 = BURN TIME CALCULATIONS
     2 = HOURLY CALCULATIONS (GRAPHIC OUTPUT)
>2
```

Line 1 is used in MOISTURE but not in SITE.

Lines 7-10 are used in SITE but not in MOISTURE.

```
 (2) MONTH OF BURN ? 1-12
>7

 (3) DAY OF BURN ? 1-31
>25

 (4) LATITUDE, DEG. ? 0 TO 90
>46

 (4) NORTH OR SOUTH OF THE EQUATOR ? N-S
>N
```

There is no latitude estimation by state abbreivation in MOISTURE. MOISTURE and SITE can now handle southern latitudes.

```
 SUNSET  = 1926.
 SUNRISE =  433.

 (5) BURN TIME ? 0000-2359
>1150
```

To obtain a 24-hour diurnal prediction, you must use a burn time of 1100 to 1159 (because of the definition of burn day).

```
 (6) FUEL MODEL ? 1-99
>5
```

No 2-fuel-model concept is allowed in MOISTURE. Fuel models are used only to provide a fuel depth for wind adjustment purposes. Custom fuel models are allowed.

```
 (11) TERRAIN SLOPE, % ? 0 TO 100
>10
```

There are no slope helps in MOISTURE as there are in SITE.

```
 (12) ELEVATION OF FIRE LOCATION, FT ? 0 TO 12000
>1000

 (13) ARE WEATHER OBSERVATIONS AT THE SAME ELEVATION
       AS THE FIRE ? Y-N
>Y
```

The same information is obtained as before, but using a new format. This applies in both SITE and MOISTURE.

```
 (14) ASPECT ? N,NE,E,SE,S,SW,W,NW
>SE

 (15) CROWN CLOSURE, % ? 0-100 OR QUIT
   (ENTER THE CLOSURE AS IF THERE WERE FOLIAGE)
>0

 (22) BURN DAY 1400 TEMPERATURE, F ? 33 TO 120 OR QUIT
>85

 (23) BURN DAY 1400 RELATIVE HUMIDITY, % ? 1 TO 100
>20

 (24) BURN DAY 1400 20-FOOT WINDSPEED, MI/H ? 0 TO 99
>5

 (25) BURN DAY 1400 CLOUD COVER, % ? 0 TO 100
>0

 (26) BURN DAY 1400 HAZINESS ? 1-4
        1=VERY CLEAR SKY
        2=AVERAGE CLEAR FOREST ATMOSPHERE
        3=MODERATE FOREST BLUE HAZE
        4=DENSE HAZE
>1

 (27) SUNSET TEMPERATURE, F ? 33 TO 120
>68

 (28) SUNSET RELATIVE HUMIDITY, % ? 1 TO 100
>30

 (29) SUNSET 20-FOOT WINDSPEED, MI/H ? 0 TO 99
>0

 (30) SUNSET CLOUD COVER, % ? 0 TO 100
>0

 (31) SUNRISE TEMPERATURE, F ? 33 TO 120
>57

 (32) SUNRISE RELATIVE HUMIDITY, % ? 1 TO 100
>35

 (33) SUNRISE 20-FOOT WINDSPEED, MI/H ? 0 TO 99
>0

 (34) SUNRISE CLOUD COVER, % ? 0 TO 100
>0

 (35) BURN TIME TEMPERATURE, F ? 33 TO 120
>70
```

There is no estimation of relative humidity for sunset, sunrise, burn time in MOISTURE (this capability is still available in SITE).

```
(36) BURN TIME RELATIVE HUMIDITY, % ? 1 TO 100
>30

(37) BURN TIME 20-FOOT WINDSPEED, MI/H ? 0 TO 99
>5

(38) BURN TIME CLOUD COVER, % ? 0 TO 100
>0

(39) BURN TIME HAZINESS ? 1-4
      1=VERY CLEAR SKY
      2=AVERAGE CLEAR FOREST ATMOSPHERE
      3=MODERATE FOREST BLUE HAZE
      4=DENSE HAZE
>1

(40) EXPOSURE TO WIND ? 1-5
   1 = EXPOSED
   2 = PARTIALLY SHELTERED
   3 = FULLY SHELTERED--OPEN STAND
   4 = FULLY SHELTERED--DENSE STAND
   5 = DIRECT ENTRY OF WIND ADJUSTMENT FACTOR
>1
```

In MOISTURE, there is no help in determining exposure to wind as there is in SITE. Option 5 is new to SITE.

```
(43) MOISTURE INITIALIZATION OPTION ? 1-5 OR QUIT

      1=1-HR FUEL MOISTURE KNOWN FOR BURN DAY -1

      2=COMPLETE WEATHER DATA FOR 3 TO 7 DAYS

      3=INCOMPLETE WEATHER DATA
        RAIN THE WEEK BEFORE THE BURN

      4=INCOMPLETE WEATHER DATA
        NO RAIN THE WEEK BEFORE THE BURN
        WEATHER PATTERN HOLDING
        (NO ADDITIONAL INPUT)

      5=INCOMPLETE WEATHER DATA
        WEATHER PATTERN CHANGING
>3

(51) NUMBER OF DAYS BEFORE THE BURN THAT RAIN OCCURRED ? 1-7
>5

(52) RAIN AMOUNT, INCHES ? .01 TO 4
>.09

(53) 1400 TEMPERATURE ON THE DAY IT RAINED, F ? 33 TO 120
>70
```

Precipitation amounts can be put in to the nearest hundredth (both SITE and MOISTURE). SITE (English) units for this input have been changed to inches.

```
 (54) SKY CONDITION FROM THE DAY IT RAINED TIL BURN DAY ? 1-3
      1=CLEAR
      2=CLOUDY
      3=PARTLY CLOUDY
>1

 MOISTURE KEYWORD ?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY HELP,STATUS
>LIST


 MOISTURE
  1--RUN OPTION--------------    2=HOURLY CALCULATIONS (GRAPHIC OUTPUT)
  2--MONTH OF BURN-----------    7.
  3--DAY OF BURN-------------   25.
  4--LATITUDE----------------   46. N
  5--BURN TIME (2400 HOURS)-- 1150.
                               433.=TIME OF SUNRISE
                              1926.=TIME OF SUNSET
  6--FUEL MODEL                  5 = BRUSH (2 FT)

 11--TERRAIN SLOPE, % -------   10.0
 12--ELEVATION OF FIRE
      LOCATION, FT ---------- 1000.0
 13--ELEVATION OF WEATHER
       OBSERVATIONS, FT------    SAME AS FIRE LOCATION
 14--ASPECT------------------    SE

>

 15--CROWN CLOSURE, % -------     .0

>

 22--BURN DAY 1400 TEMP, F --   85.0
 23--BURN DAY 1400 RH, % ----   20.0
 24--BURN DAY 1400 20-FOOT
      WIND SPEED, MI/H ------    5.0
 25--BURN DAY 1400 CLOUD
      COVER, % --------------     .0
 26--BURN DAY 1400 HAZINESS--    1=VERY CLEAR SKY


 27--SUNSET TEMPERATURE, F --   68.0
 28--SUNSET RH, % -----------   30.0
 29--SUNSET 20-FOOT
      WIND SPEED, MI/H ------     .0
 30--SUNSET CLOUD COVER, % --     .0

>
```

```
31--SUNRISE TEMPERATURE, F -   57.0
32--SUNRISE RH, % ----------   35.0
29--SUNRISE 20-FOOT
     WIND SPEED, MI/H ------     .0
34--SUNRISE CLOUD COVER, % -     .0


35--BURN TIME TEMPERATURE, F   70.0
36--BURN TIME RH, % --------   30.0
37--BURN TIME 20-FOOT
     WIND SPEED, MI/H ------    5.0
38--BURN TIME CLOUD COVER, %     .0
39--BURN TIME HAZINESS------    1=VERY CLEAR SKY
40--EXPOSURE OF FUELS TO
      THE WIND--------------    1=EXPOSED
                                 .4=WIND ADJUSTMENT FACTOR
>

43--MOISTURE INITIALIZATION
      CODE------------------    3=INCOMPLETE WEATHER DATA
                                  RAIN THE WEEK BEFORE THE BURN
51--NUMBER OF DAYS BEFORE
    BURN THAT RAIN OCCURRED     5.0
52--RAIN AMOUNT, INCHES ----     .09
53--1400 TEMPERATURE ON
     THE DAY IT RAINED, F --   70.0
54--SKY CONDITION AFTER THE
      DAY IT RAINED---------    1=CLEAR

MOISTURE KEYWORD ?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY HELP,STATUS
>RUN

PLOT VARIABLE ? 0-11

0=NO MORE GRAPHS            6=MIDFLAME WIND
1=1-HR FUEL MOISTURE        7=FUEL LEVEL WIND
2=DRY BULB TEMPERATURE      8=SHADE PERCENT
3=AIR RH                    9=PROBABILITY OF IGNITION
4=FUEL LEVEL TEMPERATURE   10=TABULAR OUTPUT
5=FUEL LEVEL RH            11=2 OR MORE PARAMETERS
                                ON SAME AXES
>10
```

Tabular output provides the values of all 9 parameters (1-9) each hour from noon until burn time.

(VERSION 4.0)

LOCAL SUN TIME (HR)	1-HR FUEL MOIS (%)	DRY BULB TEMP (F)	AIR RH (%)	FUEL LEVEL TEMP (F)	FUEL LEVEL RH (%)	MID-FLAME WIND (MI/H)	FUEL LEVEL WIND (MI/H)	SHADE (%)	PROB OF IGN (%)
1200	3.9	85.	20.	113.	8.	2.0	1.1	0.	80.
1300	3.9	85.	20.	113.	8.	2.0	1.1	0.	80.
1400	3.9	85.	20.	113.	8.	2.0	1.1	0.	80.
1500	3.2	84.	20.	108.	9.	1.6	.9	0.	80.
1600	3.1	82.	22.	101.	12.	1.3	.7	0.	80.
1700	3.1	79.	24.	91.	16.	.9	.5	0.	80.
1800	3.3	75.	26.	79.	23.	.5	.3	0.	80.
1900	3.6	70.	29.	70.	29.	.2	.1	0.	70.
2000	3.9	67.	30.	67.	30.	.0	.0	100.	70.
2100	4.1	65.	31.	65.	31.	.0	.0	100.	60.
2200	4.4	63.	32.	63.	32.	.0	.0	100.	60.
2300	4.6	62.	33.	62.	33.	.0	.0	100.	60.
2400	4.8	60.	34.	60.	34.	.0	.0	100.	60.
100	5.1	59.	34.	59.	34.	.0	.0	100.	50.
200	5.3	58.	35.	58.	35.	.0	.0	100.	50.
300	5.6	57.	35.	57.	35.	.0	.0	100.	50.
400	5.8	57.	35.	57.	35.	.0	.0	100.	50.

Probability of ignition in MOISTURE uses the predicted fuel level temperature in the prob. of ign. equations instead of the fuel temperature estimate based on air temp. and shade as in the prob. of ign. table. The result is rounded to the nearest 10%.

(VERSION 4.0)

LOCAL SUN TIME (HR)	1-HR FUEL MOIS (%)	DRY BULB TEMP (F)	AIR RH (%)	FUEL LEVEL TEMP (F)	FUEL LEVEL RH (%)	MID-FLAME WIND (MI/H)	FUEL LEVEL WIND (MI/H)	SHADE (%)	PROB OF IGN (%)
500	6.0	57.	35.	57.	35.	.1	.1	0.	50.
600	6.2	58.	35.	66.	27.	.4	.2	0.	50.
700	6.2	59.	34.	76.	20.	.7	.4	0.	50.
800	5.9	60.	34.	85.	15.	.9	.5	0.	50.
900	5.3	63.	33.	93.	12.	1.2	.7	0.	60.
1000	4.7	65.	32.	98.	11.	1.5	.9	0.	70.
1100	4.0	68.	31.	101.	10.	1.8	1.0	0.	70.
1150	4.0	70.	30.	103.	10.	2.0	1.1	0.	70.

The headings are repeated on the terminal for your convenience. They are omitted in log files.

```
PLOT VARIABLE ? 0-11

0=NO MORE GRAPHS            6=MIDFLAME WIND
1=1-HR FUEL MOISTURE        7=FUEL LEVEL WIND
2=DRY BULB TEMPERATURE      8=SHADE PERCENT
3=AIR RH                    9=PROBABILITY OF IGNITION
4=FUEL LEVEL TEMPERATURE   10=TABULAR OUTPUT
5=FUEL LEVEL RH            11=2 OR MORE PARAMETERS
                                ON SAME AXES
>1

SCALE OPTION ? 1-2
     1 = USE THE CALCULATED Y-AXIS RANGE
     2 = SET THE Y-AXIS RANGE
>1
```

The calculated y-axis range spreads the plot vertically as much as possible.

Parameter being plotted

```
        1-HR FUEL MOISTURE, %            VERSION 4.0
6.5-
   !                                     1 1
  6-                                   1
   !                                 1       1
5.5-                               1
   !                             1             1
  5-                           1
   !                         1                   1
4.5-                       1
   !                     1
  4- 1 1 1             1                           1
   !                 1
3.5-               1
   !       1     1
  3--!---!---1-1-!---!---!---!---!---!---!---!---!---!
    12  14  16  18  20  22  24   2   4   6   8  10  12
                    S                 R
                LOCAL SUN TIME (HOUR)
>
```

1 corresponds to the list number from above for this parameter

S = sunset R = sunrise

```
PLOT VARIABLE ? 0-11

0=NO MORE GRAPHS              6=MIDFLAME WIND
1=1-HR FUEL MOISTURE          7=FUEL LEVEL WIND
2=DRY BULB TEMPERATURE        8=SHADE PERCENT
3=AIR RH                      9=PROBABILITY OF IGNITION
4=FUEL LEVEL TEMPERATURE     10=TABULAR OUTPUT
5=FUEL LEVEL RH              11=2 OR MORE PARAMETERS
                                  ON SAME AXES
>11
```

More than 2 or 3 becomes too busy to be useful.

```
PARAMETER NO. 1?
0=NO MORE PARAMETERS         5=FUEL LEVEL RH
1=1-HR FUEL MOISTURE         6=MIDFLAME WIND
2=DRY BULB TEMPERATURE       7=FUEL LEVEL WIND
3=AIR RH                     8=SHADE PERCENT
4=FUEL LEVEL TEMPERATURE     9=PROBABILITY OF IGNITION
>2

PARAMETER NO. 2?
0=NO MORE PARAMETERS         5=FUEL LEVEL RH
1=1-HR FUEL MOISTURE         6=MIDFLAME WIND
2=DRY BULB TEMPERATURE       7=FUEL LEVEL WIND
3=AIR RH                     8=SHADE PERCENT
4=FUEL LEVEL TEMPERATURE     9=PROBABILITY OF IGNITION
>4
```

```
PARAMETER NO. 3?
0=NO MORE PARAMETERS        5=FUEL LEVEL RH
1=1-HR FUEL MOISTURE        6=MIDFLAME WIND
2=DRY BULB TEMPERATURE      7=FUEL LEVEL WIND
3=AIR RH                    8=SHADE PERCENT
4=FUEL LEVEL TEMPERATURE    9=PROBABILITY OF IGNITION
>0

SCALE OPTION ? 1-2
    1 = USE THE CALCULATED Y-AXIS RANGE
    2 = SET THE Y-AXIS RANGE
>2

Y-AXIS MINIMUM ? 0-200
>50

Y-AXIS MAXIMUM ? 0-200
>115
```

Let's set our own y-axis range this time.

The key to the plotted parameters corresponds to the list.

```
     1=1-HR    2=DBULB   3=RH      4=FTEMP         VERSION 4.0
     5=FRH     6=MWIND   7=FWIND   8=SHADE   9=PI
 120-
    ! 4 4 4
 110-       4
    !
 100-         4                                   4 4
    !                                           4
  90-           4
    ! 2 2 2 2                                 4
  80-         2 2 4
    !             2                         4
  70-               4                               2
    !                 4 4 4               4     2 2
  60-                       4 4 4 4       2 2 2
    !                               4 4 4
  50--!---!---!---!---!---!---!---!---!---!---!---!---!
     12  14  16  18  20  22  24   2   4   6   8  10  12
                     S                 R
                 LOCAL SUN TIME (HOUR)
>
```

Imagine the smooth curve sketched in. The steps in the line are due to the resolution of the character display.

Fuel temperature (4) plotted on top of air temperature here, so the 2's disappeared.

```
PLOT VARIABLE ? 0-11

0=NO MORE GRAPHS             6=MIDFLAME WIND
1=1-HR FUEL MOISTURE         7=FUEL LEVEL WIND
2=DRY BULB TEMPERATURE       8=SHADE PERCENT
3=AIR RH                     9=PROBABILITY OF IGNITION
4=FUEL LEVEL TEMPERATURE    10=TABULAR OUTPUT
5=FUEL LEVEL RH             11=2 OR MORE PARAMETERS
                                 ON SAME AXES
>0
```

```
 MOISTURE KEYWORD ?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY HELP,STATUS
>INPUT


 REMINDER:  'BURN DAY' STARTS AT NOON AND CONTINUES FOR 24
            HOURS.  ALL INPUTS ARE IN REFERENCE TO 'BURN DAY.'

 (1) RUN OPTION ? 1-2 OR QUIT
     1 = BURN TIME CALCULATIONS
     2 = HOURLY CALCULATIONS (GRAPHIC OUTPUT)
>1

 (2) MONTH OF BURN ? 1-12
>5

 (3) DAY OF BURN ? 1-31
>30

 (4) LATITUDE, DEG. ? 0 TO 90
>40

 (4) NORTH OR SOUTH OF THE EQUATOR ? N-S
>N

 SUNSET  = 1918.
 SUNRISE =  442.

 (5) BURN TIME ? 0000-2359
>1500

 (6) FUEL MODEL ? 1-99
>2

 *(11) TERRAIN SLOPE, % ? 0 TO 100
>10

 *(12) ELEVATION OF FIRE LOCATION, FT ? 0 TO 12000
>4500

 (13) ARE WEATHER OBSERVATIONS AT THE SAME ELEVATION
        AS THE FIRE ? Y-N
>Y

 (14) DO YOU WANT CALCULATIONS FOR ALL ASPECTS ? Y-N
>Y

 (15) CROWN CLOSURE, % ? 0-100 OR QUIT
   (ENTER THE CLOSURE AS IF THERE WERE FOLIAGE)
>10
```

Run option must be 1 for ranging input to be acceptable. If using CHANGE, be sure to change line 1 first.

*Note the * to indicate which lines allow ranges for option 1. The star did not appear in the last run when run option = 2.*

— The choice is all or only one.

```
 (16) IS FOLIAGE PRESENT ? Y-N
>Y

 (17) ARE THE TREES IN THE STAND SHADE TOLERANT? Y-N
>N

 (18) DOMINANT TREE TYPE ? 1-2
      1 = CONIFEROUS
      2 = DECIDUOUS
>1

 *(19) AVERAGE TREE HEIGHT, FT ? 10 TO 300
>50

 *(20) RATIO OF CROWN LENGTH TO TREE HEIGHT ? .1-1
>.7

 *(21) RATIO OF CROWN LENGTH TO CROWN DIAMETER ? .2-7
>3

 *(22) BURN DAY 1400 TEMPERATURE, F ? 33 TO 120 OR QUIT
>60,72,2

 THE FOLLOWING VALUES WILL BE USED
   60.0    62.0    64.0    66.0    68.0    70.0    72.0
 OK ? Y-N
>Y

 *(23) BURN DAY 1400 RELATIVE HUMIDITY, % ? 1 TO 100
>40

 *(24) BURN DAY 1400 20-FOOT WINDSPEED, MI/H ? 0 TO 99
>5

 *(25) BURN DAY 1400 CLOUD COVER, % ? 0 TO 100
>0

 (26) BURN DAY 1400 HAZINESS ? 1-4
         1=VERY CLEAR SKY
         2=AVERAGE CLEAR FOREST ATMOSPHERE
         3=MODERATE FOREST BLUE HAZE
         4=DENSE HAZE
>1

 BURN TIME IS BETWEEN 1200 AND 1600.
 BURN TIME CONDITIONS WILL BE SET TO 1400 CONDITIONS

 (40) EXPOSURE TO WIND ? 1-5
    1 = EXPOSED
    2 = PARTIALLY SHELTERED
    3 = FULLY SHELTERED--OPEN STAND
    4 = FULLY SHELTERED--DENSE STAND
    5 = DIRECT ENTRY OF WIND ADJUSTMENT FACTOR
>1
```

Shade calculations have been adjusted to better account for

1. broad, flat crowns
2. light stocking levels.

In some cases this will result in slightly different moisture predictions and different values of shade, fuel temp, fuel RH. Different predictions can be expected in these situations for versions 3.3 and later:

- timber cover at light stocking levels
- broad, flat crowns
- just before sunset and just after sunrise.

```
(43) MOISTURE INITIALIZATION OPTION ? 1-5 OR QUIT

       1=1-HR FUEL MOISTURE KNOWN FOR BURN DAY -1

       2=COMPLETE WEATHER DATA FOR 3 TO 7 DAYS

       3=INCOMPLETE WEATHER DATA
         RAIN THE WEEK BEFORE THE BURN

       4=INCOMPLETE WEATHER DATA
         NO RAIN THE WEEK BEFORE THE BURN
         WEATHER PATTERN HOLDING
         (NO ADDITIONAL INPUT)

       5=INCOMPLETE WEATHER DATA
         WEATHER PATTERN CHANGING
>4

 MOISTURE KEYWORD ?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY HELP,STATUS
>LIST


 MOISTURE
  1--RUN OPTION--------------    1=BURN TIME CALCULATIONS
  2--MONTH OF BURN-----------    5.
  3--DAY OF BURN-------------   30.
  4--LATITUDE----------------   40. N
  5--BURN TIME (2400 HOURS)-- 1500.
                                442.=TIME OF SUNRISE
                               1918.=TIME OF SUNSET
  6--FUEL MODEL                  2 = TIMBER (GRASS AND UNDERSTORY)

 11--TERRAIN SLOPE, % -------   10.0
 12--ELEVATION OF FIRE
      LOCATION, FT ---------- 4500.0
 13--ELEVATION OF WEATHER
      OBSERVATIONS, FT------     SAME AS FIRE LOCATION
 14--ASPECT-----------------     ALL ASPECTS
```

First ranging variable

```
 >

 15--CROWN CLOSURE, % -------   10.0
 16--FOLIAGE-----------------    PRESENT
 17--SHADE TOLERANCE---------    INTOLERANT
 18--DOMINANT TREE TYPE------    1=CONIFEROUS
 19--AVERAGE TREE HEIGHT, FT    50.0
 20--RATIO OF CROWN LENGTH
      TO TREE HEIGHT--------      .7
 21--RATIO OF CROWN LENGTH
      TO CROWN DIAMETER-----     3.0
```

```
>

 22--BURN DAY 1400 TEMP, F --    60.0  62.0  64.0  66.0  68.0  70.0  72.0
 23--BURN DAY 1400 RH, % ----    40.0
 24--BURN DAY 1400 20-FOOT
      WIND SPEED, MI/H ------     5.0
 25--BURN DAY 1400 CLOUD
      COVER, % -------------       .0
 26--BURN DAY 1400 HAZINESS--     1=VERY CLEAR SKY
```

Second ranging variable

```
    ***BURN TIME WEATHER = 1400 WEATHER***
```

We'll refer to this later.

```
>
 40--EXPOSURE OF FUELS TO
       THE WIND-------------      1=EXPOSED
                                   .4=WIND ADJUSTMENT FACTOR
>

 43--MOISTURE INITIALIZATION
       CODE-----------------      4=INCOMPLETE WEATHER DATA
                                    NO RAIN THE WEEK BEFORE THE BURN
                                    WEATHER PATTERN HOLDING

 MOISTURE KEYWORD ?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY HELP,STATUS
>RUN

 TABLE VARIABLE ? 0-9

 0=NO MORE TABLES            5=FUEL LEVEL RH
 1=1-HR FUEL MOISTURE        6=MIDFLAME WINDSPEED
 2=DRY BULB TEMPERATURE      7=FUEL LEVEL WINDSPEED
 3=AIR RH                    8=SHADE PERCENT
 4=FUEL LEVEL TEMPERATURE    9=PROBABILITY OF IGNITION
>1
```

```
===================================================================
1-HR FUEL MOISTURE, %                                        (V4.0)
===================================================================
             I       BURN TIME TEMPERATURE, DEG F
             I
   ASPECT    I    60.     62.     64.     66.     68.     70.     72.
             I---------------------------------------------------------
             I
     N       I    5.1     5.1     5.1     5.0     5.0     5.0     5.0
             I
     NE      I    5.3     5.3     5.2     5.2     5.2     5.2     5.1
             I
     E       I    5.2     5.1     5.1     5.1     5.1     5.0     5.0
             I
     SE      I    5.1     5.1     5.0     5.0     5.0     5.0     5.0
             I
     S       I    4.9     4.9     4.9     4.8     4.8     4.8     4.8
             I
     SW      I    4.8     4.7     4.7     4.7     4.7     4.6     4.6
             I
     W       I    4.8     4.7     4.7     4.7     4.7     4.6     4.6
             I
     NW      I    4.9     4.9     4.9     4.8     4.8     4.8     4.8
>

TABLE VARIABLE ? 0-9

0=NO MORE TABLES                5=FUEL LEVEL RH
1=1-HR FUEL MOISTURE            6=MIDFLAME WINDSPEED
2=DRY BULB TEMPERATURE          7=FUEL LEVEL WINDSPEED
3=AIR RH                        8=SHADE PERCENT
4=FUEL LEVEL TEMPERATURE        9=PROBABILITY OF IGNITION
>0

MOISTURE KEYWORD ?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY HELP,STATUS
>CHANGE

CHANGE WHICH LINE ? 0-59
  (0 MEANS NO MORE CHANGES)
>5

(5) BURN TIME ? 0000-2359
>1800

SINCE YOU HAVE CHANGED BURN TIME, YOU MAY ALSO
WANT TO CHANGE BURN TIME WEATHER
(LINES 35 THROUGH 39)
```

This column assumes a burn time temperature of 60° on each aspect. Note the expected variation in 1-hr moisture depending on aspect.

The moisture is printed to the nearest tenth of a percent to show trends in variation. The nearest percent is close enough for all practical purposes.

Let's try CHANGE for the next run.

```
 CHANGE WHICH LINE ? 0-59
   (0 MEANS NO MORE CHANGES)
>0

 MOISTURE KEYWORD ?
 ENTER INPUT,LIST,CHANGE,RUN,QUIT,
       TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
       ENGLISH,METRIC,PERCENT,DEGREES,
       COMMENT,KEY HELP,STATUS
>LIST


 MOISTURE
  1--RUN OPTION--------------    1=BURN TIME CALCULATIONS
  2--MONTH OF BURN-----------    5.
  3--DAY OF BURN-------------   30.
  4--LATITUDE----------------   40. N
  5--BURN TIME (2400 HOURS)-- 1800.
                               442.=TIME OF SUNRISE
                              1918.=TIME OF SUNSET
  6--FUEL MODEL                  2 = TIMBER (GRASS AND UNDERSTORY)

 11--TERRAIN SLOPE, % -------   10.0
 12--ELEVATION OF FIRE
      LOCATION, FT ---------- 4500.0
 13--ELEVATION OF WEATHER
       OBSERVATIONS, FT------    SAME AS FIRE LOCATION
 14--ASPECT------------------    ALL ASPECTS

>

 15--CROWN CLOSURE, % -------   10.0
 16--FOLIAGE-----------------    PRESENT
 17--SHADE TOLERANCE---------    INTOLERANT
 18--DOMINANT TREE TYPE------    1=CONIFEROUS
 19--AVERAGE TREE HEIGHT, FT    50.0
 20--RATIO OF CROWN LENGTH
      TO TREE HEIGHT--------      .7
 21--RATIO OF CROWN LENGTH
      TO CROWN DIAMETER-----     3.0

>

 22--BURN DAY 1400 TEMP, F --   60.0  62.0  64.0  66.0  68.0  70.0  72.0
 23--BURN DAY 1400 RH, % ----   40.0
 24--BURN DAY 1400 20-FOOT
      WIND SPEED, MI/H ------    5.0
 25--BURN DAY 1400 CLOUD
      COVER, % --------------     .0
 26--BURN DAY 1400 HAZINESS--    1=VERY CLEAR SKY
```

```
35--BURN TIME TEMPERATURE, F   60.0  62.0  64.0  66.0  68.0  70.0  72.0
36--BURN TIME RH, % --------   40.0
37--BURN TIME 20-FOOT
     WIND SPEED, MI/H ------    5.0
38--BURN TIME CLOUD COVER, %     .0
40--EXPOSURE OF FUELS TO
      THE WIND--------------    1=EXPOSED
                                 .4=WIND ADJUSTMENT FACTOR
>

43--MOISTURE INITIALIZATION
      CODE------------------    4=INCOMPLETE WEATHER DATA
                                  NO RAIN THE WEEK BEFORE THE BURN
                                  WEATHER PATTERN HOLDING
```

See the listing from the previous run. These values were reset because of burn time choice. Be careful when using CHANGE to set up for the next run. Always check your listing to see if it's what you intended. (Now there are 3 ranging variables.)

```
MOISTURE KEYWORD ?
ENTER INPUT,LIST,CHANGE,RUN,QUIT,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY HELP,STATUS
QUIT


FINISH MOISTURE -- BACK TO FIRE2



FIRE2 KEYWORD ?
ENTER IGNITE,MOISTURE,RH,CUSTOM,
      TERSE,WORDY,PAUSE,NOPAUSE,LOG,NOLOG,
      ENGLISH,METRIC,PERCENT,DEGREES,
      COMMENT,KEY,HELP,STATUS,QUIT
QUIT


DO YOU  R E A L L Y  WANT TO TERMINATE THIS RUN ?  Y-N
Y

PART OF THIS RUN MAY HAVE BEEN LOGGED.
THE FILE NAME IS:  LOGFIL
PRINT THE FILE NOW AND DELETE IT.


FIRE2 RUN TERMINATED.
********************************
```

APPENDIX B: INPUT/OUTPUT REFERENCE SHEETS

This appendix includes input/output reference sheets for all modules of the FIRE1 and FIRE2 programs of BEHAVE. Some have the same items and line numbers as those given in Part 1 of this manual (DIRECT, SIZE, CONTAIN, DISPATCH), some are revised to reflect the changes described in the body of this paper (SPOT, SITE), and others are for new modules (SCORCH, MORTALITY, MAP, SLOPE, MOISTURE, IGNITE, RH). To avoid confusion with previous versions, a date is given at the bottom of each sheet.

The information on each sheet includes the item name, line number (as used by the CHANGE command), an * to indicate that a range of values is allowed, English and metric units, and comments. Only one blank is given for each input and output value. These are reference sheets rather than worksheets. A person will normally use a computer printout as a record of a run rather than writing the results on a worksheet. This is especially the case when a range of values is entered for two input values and the resulting output is a series of 7 x 7 tables.

These input/output sheets are alphabetized by module name. Refer to figure 3 for the relationship among the modules.

CONTAIN Module Input/Output
(FIRE1 program)

	UNITS English	UNITS Metric		COMMENTS
INPUT				
1 Mode of attack 1 = Head 2 = Rear			____	Direct attack
2 Run option 1 = Compute line building rate 2 = Compute burned area			____	
*3 Forward rate of spread	ch/h	m/min	____	May come from SIZE linked to DIRECT
*4 Initial fire size	ac	ha	____	
*5 Length-to-width ratio			____	
*6 Burned area target	ac	ha	____	If line building rate is computed
*7 Total line building rate	ch/h	m/min	____	If burned area is computed Total line building rate is twice the rate per flank
OUTPUT				
1 Total length of line	ch	m	____	Perimeter of burned area
2 Total containment time	h	h	____	
3 Total line building rate	ch/h	m/min	____	
or				
3 Final fire size	ac	ha	____	

*A range of inputs is allowed

DIRECT Module Input/Output
(FIRE1 program)

		UNITS English	UNITS Metric		COMMENTS
INPUT					
1	Fuel model			——	Enter 0 for two-fuel-model concept input
*2	1-h fuel moisture	%	%	——	
*3	10-h fuel moisture	%	%	——	If the fuel model has this size class
*4	100-h fuel moisture	%	%	——	
*5	Live herbaceous fuel moisture	%	%	——	
*6	Live woody fuel moisture	%	%	——	
*7	Midflame windspeed	mi/h	km/h	——	
*8	Slope	% or deg	% or deg	——	Units set using keywords PERCENT and DEGREES
*9	Direction of wind vector, deg clockwise from uphill	deg	deg	——	If windspeed is not zero. Direction that the wind is pushing the fire
*10	Direction for spread calculations, deg clockwise from uphill (or from the wind vector if slope is zero)	deg	deg	——	Direction of maximum spread can be calculated
OUTPUT					
1	Rate of spread	ch/h	m/min	——	Fire behavior in the direction specified in input line 10
2	Heat per unit area	Btu/ft^2	kJ/m^2	——	
3	Fireline intensity	Btu/ft/s	kW/m	——	
4	Flame length	ft	m	——	
5	Reaction intensity	Btu/ft^2/min	kW/m^2	——	
6	Effective windspeed	mi/h	km/h	——	
7	Direction of maximum spread, deg clockwise from uphill	deg	deg	——	

*A range of inputs is allowed

DISPATCH Module Input/Output
(FIRE1 program)

	UNITS English	UNITS Metric		COMMENTS
INPUT				
1 Fuel model			——	
2 Dead fuel moisture	%	%	——	1-h, 10-h, and 100-h
3 Live fuel moisture	%	%	——	Woody and herbaceous
4 20-foot windspeed	mi/h	km/h	——	Upslope wind
5 Wind adjustment factor			——	Midflame wind is 20-ft wind times wind adj. factor
6 Slope	% or deg	% or deg	——	
7 Elapsed time from ignition to attack	h	h	——	
8 Total line building rate	ch/h	m/min	——	Twice the rate per flank
OUTPUT				
Forward rate of spread	ch/h	m/min	——	
Heat per unit area	Btu/ft^2	kJ/m^2	——	
Fireline intensity	Btu/ft/s	kW/m	——	
Flame length	ft	m	——	
Perimeter at time of attack	ch	m	——	
Area at time of attack	ac	ha	——	
Head attack:				
Elapsed time from attack to containment	h	h	——	
Total length of line	ch	m	——	Perimeter of burned area
Final fire size	ac	ha	——	
Rear attack:				
Elapsed time from attack to containment	h	h	——	
Total length of line	ch	m	——	Perimeter of burned area
Final fire size	ac	ha	——	

IGNITE Module Input/Output
(FIRE2 program)

		UNITS			COMMENTS
		English	*Metric*		
INPUT					
*1	Dry bulb temperature	°F	°C	____	
*2	1-h fuel moisture	%	%	____	
*3	Shade	%	%	____	
OUTPUT					
	Probability of ignition	%	%	____	

*A range of values is allowed.

MAP Module Input/Output
(FIRE1 program)

		UNITS English	UNITS Metric		COMMENTS
INPUT					
1	Map scale	rep frac or in/mi	rep frac or cm/km	____	
2	Units option 1 = spread distance 2 = spot distance 3 = rate of spread			____	
*3	Spread distance	ch	m	____	If units option = 1
*4	Maximum spotting distance	mi	km	____	If units option = 2
*5	Rate of spread	ch/h	m/min	____	If units option = 3
*6	Elapsed time	h	h	____	If units option = 3
OUTPUT					
	Map spread distance	in	cm	____	If units option = 1, 3
or					
	Map maximum spotting distance	in	cm	____	If units option = 2
					In the direction of the wind

*A range of values is allowed

MOISTURE Module Output
(FIRE2 program)

(Use input sheets for SITE and MOISTURE combined)

		UNITS			COMMENTS
		English	*Metric*		
1	1-h fuel moisture	%	%	____	
2	Dry bulb temperature	°F	°C	____	
3	Air RH	%	%	____	
4	Fuel level temperature	°F	°C	____	
5	Fuel level RH	%	%	____	
6	Midflame windspeed	mi/h	km/h	____	
7	Fuel level windspeed	mi/h	km/h	____	
8	Shade	%	%	____	
9	Probability of ignition	%	%	____	

MORTALITY Module Input/Output
(FIRE1 program)

	UNITS English	UNITS Metric		COMMENTS
INPUT				
*1 Scorch height	ft	m	——	May come from SCORCH
*2 Tree height	ft	m	——	
*3 Crown ratio			——	Ratio of crown length to tree height
*4 Bark thickness Direct input	in	cm	——	
or from: Species 1 = western larch, Douglas-fir 2 = western hemlock 3 = Engelmann spruce, western red cedar 4 = lodgepole pine, subalpine fir			——	
DBH	in	cm	——	
OUTPUT				
1 Mortality level	%	%	——	
2 Crown volume scorch	%	%	——	

* Range of values is allowed.

RH Module Input/Output
(FIRE2 program)

	UNITS *English*	*Metric*		COMMENTS
INPUT				
*1 Dry bulb temperature	°F	°C	——	
*2 Wet bulb temperature	°F	°C	——	
*3 Elevation	ft	m	——	
OUTPUT				
1 Relative humidity	%	%	——	
2 Dew point	°F	°C	——	

* A range of values is allowed.

SCORCH Module Input/Output
(FIRE1 program)

	UNITS English	UNITS Metric		COMMENTS
INPUT				
*1 Ambient air temperature	°F	°C	——	
*2 Flame length	ft	m	——	May come from DIRECT
*3 Midflame windspeed	mi/h	km/h	——	May come from DIRECT
OUTPUT				
Crown scorch height	ft	m	——	

* A range of values is allowed.

SITE and MOISTURE Module Input
(SITE in FIRE1 program; MOISTURE in FIRE2 program)

	UNITS English	UNITS Metric		COMMENTS
INPUT				
1 MOISTURE run option 1 = Burn time calculations 2 = Hourly calculations (graphic output)			____	MOISTURE only
TIME AND LOCATION				
2 Month of burn			____	
3 Day of burn			____	
4 Latitude	deg	deg	____	
State			____	SITE only If latitude is not known
5 Burn time (2400 hour)			____	
FUEL MODEL				
6 Fuel model			____	
FUEL MOISTURE				
7 10-h fuel moisture	%	%	____	SITE only If this size class is in the fuel model (items 7–10)
8 100-h fuel moisture	%	%	____	
9 Live herbaceous moisture	%	%	____	
10 Live woody moisture	%	%	____	
SLOPE, ELEVATION, ASPECT				
*11 Slope	% or deg	% or deg	____	Units set using keywords PERCENT or DEGREES
Map scale	rep frac or in/mi	rep frac or cm/km	____	SITE only If slope is not known (Map scale through Number of contour intervals)
Contour interval	ft	m	____	
Map distance	in	cm	____	
Number of contour intervals			____	
*12 Elevation of fire location	ft	m	____	

* A range of values is allowed in MOISTURE only, run option 1.

	English	Metric		COMMENTS
SLOPE, ELEVATION, ASPECT				
13 Elevation of T/RH obs.	ft	m	___	
*14 Aspect (N,NE,E,SE,S, SW,W,NW)			___	If slope is not zero
TIMBER OVERSTORY DESCRIPTION				
*15 Crown closure	%	%	___	
16 Foliage present or absent			___	If crown closure is not zero
17 Shade tolerant or intolerant			___	
18 Dominant tree type 1 = Coniferous 2 = Deciduous			___	
*19 Average tree height	ft	m	___	
*20 Ratio of crown length to tree height			___	
*21 Ratio of crown length to crown diameter			___	
EARLY AFTERNOON WEATHER				
*22 Burn day 1400 temperature	°F	°C	___	Required input If burn time is between 1200 and 1600, 1400 weather is used for burn time weather.
*23 Burn day 1400 relative humidity	%	%	___	
*24 Burn day 1400 20-ft windspeed	mi/h	km/h	___	
*25 Burn day 1400 cloud cover	%	%	___	
26 Burn day 1400 haziness 1 = very clear sky 2 = average clear forest atmosphere 3 = moderate forest blue haze 4 = dense haze or light to moderate smoke			___	

* A range of values is allowed in MOISTURE only, run option 1.

SITE and **MOISTURE** Module Input, continued:

	UNITS *English*	*Metric*		COMMENTS
SUNSET WEATHER				
*27 Sunset temperature	°F	°C	____	For burn time after sunset and before 1200 (12 16 SS SR 12)
*28 Sunset relative humidity	%	%	____	
*29 Sunset 20-ft windspeed	mi/h	km/h	____	
*30 Sunset cloud cover	%	%	____	
SUNRISE WEATHER				
*31 Sunrise temperature	°F	°C	____	For burn time after sunrise and before 1200 (12 16 SS SR 12)
*32 Sunrise relative humidity	%	%	____	
*33 Sunrise 20-ft windspeed	mi/h	km/h	____	
*34 Sunrise cloud cover	%	%	____	
BURN TIME WEATHER				
*35 Burn time temperature	°F	°C	____	For burn time after 1600 or before 1200 (12 16 SS SR 12)
*36 Burn time relative humidity	%	%	____	
*37 Burn time 20-ft windspeed	mi/h	km/h	____	
*38 Burn time cloud cover	%	%	____	For burn time (after 1600 & before SS) or (after SR and before 1200) (12 16 SS SR 12)

39 Burn time haziness ____

For burn time after sunrise and before 1200

12 16 SS SR 12

- 1 = very clear sky
- 2 = average clear forest atmosphere
- 3 = moderate forest blue haze
- 4 = dense haze or light to moderate smoke

BURN TIME WIND

40 Exposure of fuels to the wind ____

- 0 = Don't know (SITE only)
- 1 = Exposed
- 2 = Partially sheltered
- 3 = Fully sheltered—open stand
- 4 = Fully sheltered—closed stand
- 5 = Direct entry of wind adjustment factor

* A range of values is allowed in MOISTURE only, run option 1.

	UNITS English	UNITS Metric		COMMENTS
BURN TIME WIND				
41 Burn time direction of wind vector, degrees clockwise from uphill			___	SITE only
42 Direction for spread calculations, degrees clockwise from uphill or from wind vector if slope = 0 (direction of maximum spread can be calculated)			___	SITE only
MOISTURE INITIALIZATION OPTION				
43 Moisture initialization option 1 = Fine fuel moisture known the day before the burn 2 = Complete weather available for 3 to 7 days prior to the burn 3 = Incomplete weather data and it rained the week before the burn 4 = Incomplete weather data, no rain the week before the burn, and weather pattern is stable (no additional input) 5 = Incomplete weather data; weather pattern changing			___	
FINE FUEL MOISTURE KNOWN FOR THE DAY BEFORE THE BURN				
*44 Burn day -1 fine fuel moisture	%	%	___	For moisture initialization option 1

COMPLETE WEATHER AVAILABLE FOR 3 TO 7 DAYS PRIOR TO THE BURN

45 Number of days of weather ___

	-1	-2	-3	-4	-5	-6	-7	
46 Burn day -x 1400 temperature, °F or °C	___	___	___	___	___	___	___	For moisture initialization option 2
47 Burn day -x 1400 relative humidity, %	___	___	___	___	___	___	___	
48 Burn day -x 1400 20-ft windspeed, mi/h or km/h	___	___	___	___	___	___	___	
49 Burn day -x 1400 cloud cover, %	___	___	___	___	___	___	___	
50 Burn day -x rain amount, hundredths of an inch or cm	___	___	___	___	___	___	___	

* A range of values is allowed in MOISTURE only, run option 1.

SITE and **MOISTURE** Module Input, continued:

		UNITS			COMMENTS
		English	*Metric*		
INCOMPLETE WEATHER DATA; RAIN THE WEEK BEFORE THE BURN					
*51	Number of days before the burn that rain occurred			____	For moisture initialization option 3
*52	Rain amount	hundredths of an inch	cm	____	
*53	1400 temperature on the day it rained	°F	°C	____	
54	Sky condition from the day it rained until burn day 1 = clear 2 = cloudy 3 = partly cloudy			____	
INCOMPLETE WEATHER DATA; NO RAIN THE WEEK BEFORE THE BURN; WEATHER PATTERN HOLDING					
	No additional input				For moisture initialization option 4
INCOMPLETE WEATHER DATA; WEATHER PATTERN CHANGING					
*55	Burn day -1 1400 temperature	°F	°C	____	For moisture initialization option 5
*56	Burn day -1 1400 relative humidity	%	%	____	
*57	Burn day -1 1400 20-ft windspeed	mi/h	km/h	____	
*58	Burn day -1 1400 cloud cover	%	%	____	
59	Weather condition prior to burn day -1 1 = hot and dry 2 = cool and wet 3 = between 1 and 2			____	

*A range of values is allowed in MOISTURE only, run option 1.

SITE Module Output
(FIRE1 program)

	UNITS English	Metric		COMMENTS
INTERMEDIATE VALUES				
Time of sunset			____	
Time of sunrise			____	
Wind adjustment factor			____	
Fuel surface temperature	°F	°C	____	
Fuel level relative humidity	%	%	____	
Percent shade	%	%	____	
Fine dead fuel moisture	%	%	____	
BASIC INPUT				
Fuel model			____	Corresponds to DIRECT input and output
1-h fuel moisture	%	%	____	
10-h fuel moisture	%	%	____	
100-h fuel moisture	%	%	____	
Live herbaceous fuel moisture	%	%	____	
Live woody fuel moisture	%	%	____	
Midflame windspeed	mi/h	km/h	____	
Slope	%	%	____	
Direction of wind vector, degrees clockwise from uphill (or from the wind vector if slope is zero)	deg	deg	____	
Direction for spread calculations, degrees clockwise from uphill (or from the wind vector if slope is zero)	deg	deg	____	

OUTPUT	UNITS *English*	*Metric*		COMMENTS
Rate of spread	ch/h	m/min	_____	
Heat per unit area	Btu/ft^2	kJ/m^2	_____	
Fireline intensity	Btu/ft/s	kW/m	_____	
Flame length	ft	m	_____	
Reaction intensity	Btu/ft^2/min	kW/m^2	_____	
Effective windspeed	mi/h	km/h	_____	
Direction of maximum spread, degrees clockwise from uphill	deg	deg	_____	

MOISTURE Module Output (FIRE2 program)

		UNITS			COMMENTS
		English	*Metric*		
1	1-h fuel moisture	%	%	____	
2	Dry bulb temperature	°F	°C	____	
3	Air RH	%	%	____	
4	Fuel level temperature	°F	°C	____	
5	Fuel level RH	%	%	____	
6	Midflame windspeed	mi/h	km/h	____	
7	Fuel level windspeed	mi/h	km/h	____	
8	Shade	%	%	____	
9	Probability of ignition	%	%	____	

SIZE Module Input/Output
(FIRE1 program)

	UNITS English	UNITS Metric		COMMENTS
INPUT				
*1 Rate of spread	ch/h	m/min	____	May come from DIRECT
*2 Effective windspeed	mi/h	km/h	____	May come from DIRECT
*3 Elapsed time	h	h	____	
OUTPUT				
1 Area	ac	ha	____	
2 Perimeter	ch	m	____	
3 Length-to-width ratio			____	
4 Forward spread distance	ch	m	____	
5 Backing spread distance	ch	m	____	
6 Maximum width of fire	ch	m	____	

*A range of values is allowed.

SLOPE Module Input/Output
(FIRE1 program)

	UNITS English	UNITS Metric		COMMENTS
INPUT				
1 Map scale	rep frac or in/mi	rep frac or cm/km	____	Can enter map scale either way
*2 Contour interval	ft	m	____	
*3 Map distance	in	cm	____	
*4 Number of contour intervals			____	
OUTPUT				
1 Slope	% or deg	% or deg	____	Units set using keywords PERCENT or DEGREES
2 Elevation change	ft	m	____	
3 Horizontal distance	ft	m	____	

* A range of values is allowed.

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SPOT Module Input/Output
(FIRE1 program)

		UNITS English	UNITS Metric		COMMENTS
INPUT					
1	Firebrand source 1 = torching trees 2 = burning pile 3 = wind-driven surface fire			____	
*2	Mean cover height	ft	m	____	For torching trees or burning pile
*3	20-ft windspeed	mi/h	km/h	____	May come from DIRECT for wind-driven surface fire
*4	Ridge-to-valley elevation difference	ft	m	____	
*5	Ridge-to-valley horizontal distance	mi	km	____	If ridge-to-valley elevation difference is not equal to zero
6	Spotting source location 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop			____	
7	Tree species 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa pine, lodgepole pine 5 = white pine 6 = balsam fir, grand fir 7 = slash pine, longleaf pine 8 = pond pine, shortleaf pine 9 = loblolly pine			____	For torching trees
*8	Torching tree DBH	in	cm	____	
*9	Torching tree height	ft	m	____	
*10	Number of trees torching together			____	
*11	Continuous flame height	ft	m	____	For burning pile
*12	Flame length	ft	m	____	For wind-driven surface fire May come from DIRECT
OUTPUT					
	Maximum spot fire distance	mi	km	____	

*A range of values is allowed.

Andrews, Patricia L.; Chase, Carolyn H. 1989. BEHAVE: fire behavior prediction and fuel modeling system—BURN subsystem, Part 2. Gen. Tech. Rep. INT-260. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 93 p.

This is the third publication describing the BEHAVE system of computer programs for predicting behavior of wildland fires. This publication adds the following predictive capabilities: distance firebrands are lofted ahead of a wind-driven surface fire, probabilities of firebrands igniting spot fires, scorch height of trees, and percentage of tree mortality. The system includes a separate module for graphing moisture content of fine, dead fuels. Basic assumptions, limitations, and application of the prediction models are discussed. Previous publications in the BEHAVE series are BEHAVE: fire behavior prediction and fuel modeling system—FUEL subsystem (Burgan and Rothermel 1984), and BEHAVE: fire behavior prediction and fuel modeling system—BURN subsystem, Part 1 (Andrews 1986).

KEYWORDS: wildland fire, fire management, fire effects, firebrand, fire ignition, tree mortality

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)